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Cover Story

54 NEPTUNE RISING

Step aside, Pluto. The more we learn about the outermost bona fide planet, the more it proves to have been a potent force in the young days of the solar system. And who can resist an atmosphere that could rain diamonds?

By CURTIS RIST

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60 TO SAVE A WATERING HOLE

The fate of a good portion of Europe's and Asia's birds depends on a small wildlife sanctuary in Israel. Fortunately, commando-turned-ornithologist Reuven Yosef seems willing to risk his life to defend it.

By MARK CHERRINGTON

66 SWEAT TECH

If American athletes win gold medals at the Sydney Olympics, part of the credit should go to the scientists who have been retooling their equipment.

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Conjuring up true-to-life renderings of long-extinct creatures from jumbled piles of bones involves equal parts educated guesswork and complete artistic fancy.

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Right now vascular surgery is a one-shot experiment performed in real time, but Charles Taylor will give surgeons a chance to test their hypotheses before they walk into the operating room.

By WILLIAM SPEED WEED

86 BIOBOTS

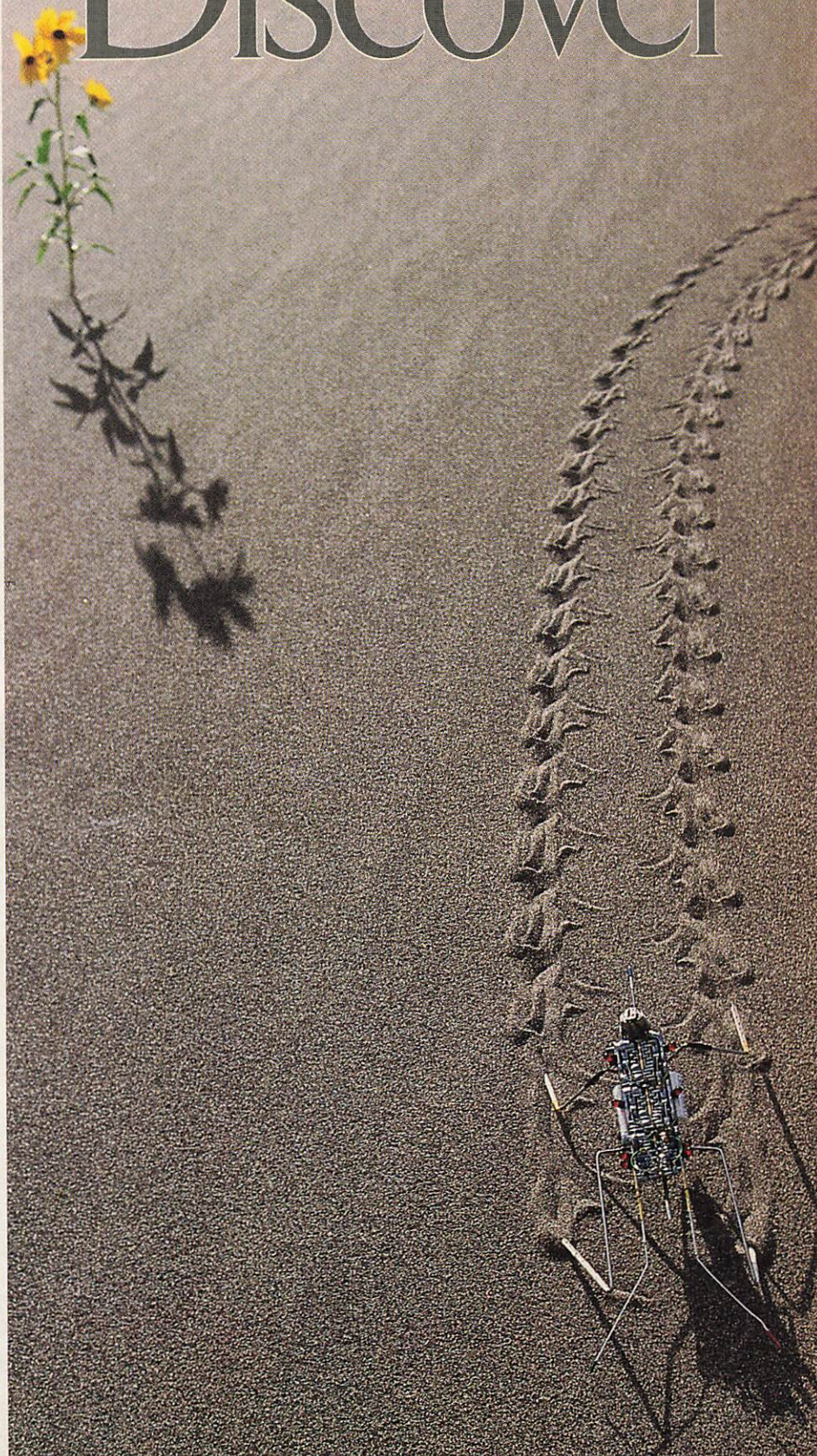
The movement to copy nature's critters in robotics labs around the world has produced some remarkably lifelike machines with extraordinary capabilities.

By PETER MENZEL AND FAITH D'ALUISIO

ON THE COVER: THE SOUTH POLE OF NEPTUNE, AS SEEN BY VOYAGER 2; PHOTOGRAPH FROM NASA.

RIGHT: PHYSICIST MARK W. TILDEN CONSTRUCTED UNIBUG 1.0 AT HOME. ITS LEGS GIVE A ROCKETTES-STYLE KICK TO SCAMPER ACROSS SAND AND OTHER TERRAIN. SEE PAGE 86 FOR MORE BIOBOTS.

Discover



FIFTY YEARS OF ASTRONOMICAL EXCELLENCE

The National Science Foundation is dedicated to making America's scientists the most productive in the world. The means of accomplishing that goal for astronomy have changed significantly over the past five decades, mirroring the changes in astronomy itself.

In 1950 the workhorses of astronomy were optical telescopes. But the only large telescopes in existence were in the hands of private institutions and few astronomers had access to them. NSF responded by creating some of the finest observatories in the world, which gave access to all astronomers on the basis of scientific merit. Perhaps most famous of these is Kitt Peak in Arizona. However, it is far from alone. The Cerro Tololo Inter-American Observatory in Chile gives U.S. astronomers access to the southern sky. The kilometer-wide radio dish in Arecibo, Puerto Rico, and the Very Large Array (VLA) of radio telescopes in New Mexico are easily the most productive radio observatories in the world. NSF-funded solar telescopes permit study of the sun from its outer atmosphere to its core.

These facilities have fueled what many consider to be the golden age of astronomy. Now, they are about to be augmented by an entirely new class of

telescopes with capacities unthinkable in 1950.

The Gemini Observatories, a collaboration between the NSF and six foreign countries, has delivered twin eight-meter telescopes, in Hawaii and Chile. Each instrument supports a precision-polished mirror thin enough to be flexed by computer-controlled

telescopes will use to collect and analyze light are pushing digital imaging and data handling technology to their current limits and beyond.

The Laser Interferometer Gravitational Wave Observatory (LIGO) is easily the most exotic of the new generation of telescopes because it is not designed to detect radiation.

Rather, it will search for gravitational waves. Albert Einstein predicted that the energy involved in spectacular events such as supernova explosions and the interaction of extraordinarily heavy objects known as neutron stars revolving about each other would create waves in the fabric of space itself. Physicists designed LIGO to detect such waves, and in the process provide clues to the behavior of matter under circumstances that no laboratory can duplicate.

More observatories are on the drawing board. A recent survey of U.S. astronomy by the National Research Council calls for an NSF-funded Giant Segmented Mirror Telescope that will trace the evolution of galaxies.

Observatories are essential to the story of NSF-funded astronomical research, but not the story itself. The extraordinary range of research conducted by NSF-sponsored individuals and small



The Gemini North Telescope in Hawaii will reveal unprecedented detail of the universe. This view shows the Gemini North dome and telescope, with shutters open.

Photo courtesy: Neelon Crawford/Polar Fine Arts, 1999.

actuators but large enough to serve as the foundation for a comfortably-sized house. With a new generation of adaptive optics, these telescopes will produce images in the infrared region of the spectrum that will rival the resolution of the Hubble Space Telescope. And the instruments these

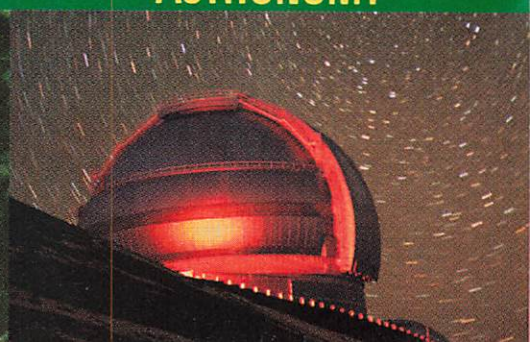
ENVIRONMENT



NANOTECHNOLOGY



ASTRONOMY





FIFTY YEARS OF SUPPORTING SCIENCE

Established in 1950, the National Science Foundation (NSF) is the federal government's only agency dedicated to the support of education and fundamental research in all scientific and engineering disciplines. NSF's mission is to ensure that the United States maintains leadership in scientific and engineering disciplines, in scientific discovery and in the development of new technologies. NSF has achieved this mission repeatedly over the past 50 years.

In a series of six articles, we will highlight key scientific advances enabled by NSF support that have had a beneficial impact on humankind.

This third article is a look at the agency's role in a broad issue that took an increasing significance as one decade followed another: Astronomy.

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teams makes this the golden age of astronomy.

In 1950, astronomers had no way to discover whether planets existed beyond our solar system. In recent years, astronomers backed by NSF have detected more than forty planets orbiting nearby stars. Although most of these are the size of Jupiter or Saturn, the hope of detecting an Earth-sized planet no longer remains exclusively the realm of science fiction.

Observational astronomers wondered if black holes really existed and, if so, whether it would ever be possible to detect them. Formed from the remnants of collapsed stars, black holes are so dense that not even light can escape their force of gravity. Now, NSF-funded researchers have not only identified black holes, by measuring the gravitational influence it has on stars that orbit it, they have even found evidence for one at the center of the Milky Way galaxy. It is a true giant, with a mass equal to 2.6 million times that of the sun.

In the late 1950s, military satellites detected intense, random flashes of radiation in the sky. Astronomers still understand little about these gamma ray bursts, that occur about once a day on average. But with NSF support, they have made the best measurements of a burst so far. They have concluded that the explosion of the gamma ray burst released more energy in its first 15

seconds, than the sun will over its entire lifetime; that it appears to be expanding at nearly the speed of light; and that it is located roughly seven billion light years from Earth.

In 1950 astronomers knew that the universe was expanding. Conflicting evidence made it unclear whether it would continue to expand forever or would eventually reverse direction and collapse in on itself. In one of the great results of twentieth century science, NSF-funded astronomers have shown both that the universe does not contain enough matter in the universe to slow the expansion, and that the rate of expansion actually increases with distance. Why? Nobody knows yet. But this is an observational result that goes to the very heart of cosmology.

The advances continue. NSF-funded astronomers working on two projects that used instruments aboard high-flying balloons recently obtained images of the infant universe at unprecedented detail. Their instruments detected radiation emitted soon after the Big Bang, measuring the smoothness and curvature of space, which indicates that the geometry of the universe is flat, not curved.

Never have astronomers had tools of such quality, precision and power. Never have they had more tantalizing research topics to explore. And never have more minds focused on such issues.

EDUCATION



INFORMATION TECHNOLOGY



BIO-COMPLEXITY



Discover



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How spiders are helping chemists find wonder drugs; why crack babies face a better future than anyone guessed; how flying pumpkins give astronomers a lift; and what a new fossil exposes about the softer side of crocodiles.

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Computers that recognize your face will soon be able to unlock your house, protect your personal files, even take care of paying for the groceries.

By SIMSON GARFINKEL

34 THE BIOLOGY OF . . . MORNING SICKNESS

You don't have to be a vegetarian to be disgusted by a T-bone steak—you might just be pregnant.

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What could push a happy honeymooner into a deep depression at 30,000 feet?

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Limber your fingers, retrieve messy memories of high-school geometry, and surrender to your baser impulses.

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104 BRAINWORKS

Learn to draw a picture of how your brain sees your body.

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LEFT: A PROTEIN IN THE VENOM OF THE CHILE ROSE TARANTULA MIGHT HELP PREVENT DEATHS FROM HEART ATTACKS; SEE R&D, PAGE 22.



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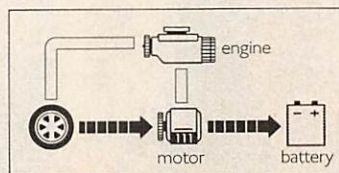
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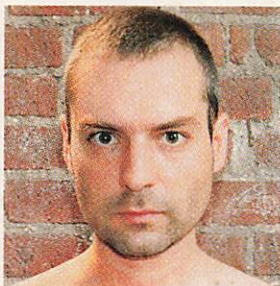
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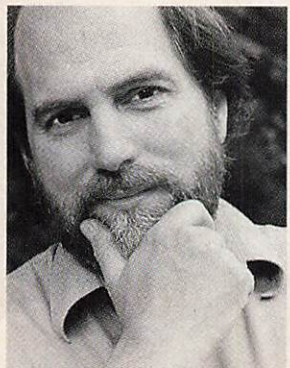


DAVID EWING DUNCAN A fascination with "the marriage of science and muscle and sweat" impelled Duncan to report on the ways in which sports are being transformed by technology ("Sweat Tech," page 66). Duncan was dazzled by the athletes' drive, but he was disturbed by the disadvantage under which teams without access to the new gizmos may labor. "My feeling is that when you're playing a game of any sort, the rules should be equal for everyone," he says. "Some critics have said that those who are coming with just their own skin on won't be able to compete with these new high-tech suits." Duncan's work has appeared in *The Atlantic Monthly*, *Harper's*, and *Smithsonian*.

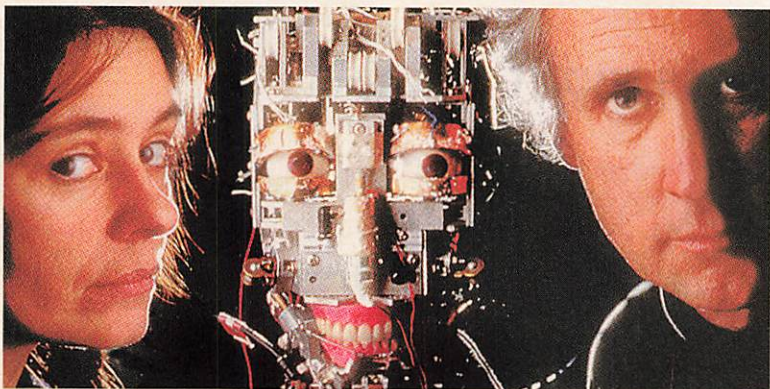
RAIMUND KOCH Munich-born photographer Koch finds himself drawn toward technology—as exemplified by his shots of smart swimsuits and SuperBikes ("Sweat Tech," page 66). "Some of those technical devices are beautiful and very powerful, almost like artwork," says Koch, who is also known for his coverage of the contemporary art world. In private life, however, he's a low-tech sort of fellow, eschewing even a TV. "I'm a minimalist," he says. "I try to carry as little as possible to get the job done. Actually, I had a cell phone last summer, and I threw it out." Koch's photos have appeared in *Wired* and *Condé Nast Traveler*.



MARK CHERRINGTON In pursuit of a good story Cherrington has journeyed from the jungle to the tundra. As the editor of *Earthwatch*, he has covered Komodo dragons in Indonesia and black rhinos in Zimbabwe, as well as the ecology of Lake Baikal during the Soviet era, when he was briefly suspected of being an agent for the CIA. In Israel for *Discover*, he was moved by the drama of the landscape, a powerful backdrop for ornithologist Reuven Yosef's fight to protect vast flocks of birds that fly over the country ("To Save a Watering Hole," page 60). "It was clear that he was a firebrand," says Cherrington. "What he was working on was so important, and he was meeting such enormous and violent resistance." Cherrington's articles have also appeared in *Wildlife Conservation* and *The Boston Globe*.



PETER MENZEL & FAITH D'ALUISIO More than 100 robots, of all shapes and sizes, inhabit the pages of Menzel and D'Aluisio's book, *Robo sapiens* (excerpted this month, beginning on page 86). To capture these curious beasts, the pair traveled the world, Menzel photographing and D'Aluisio interviewing their inventors. "They're friendly, receptive, and smart—possessed by their ideas but all very eager to share their knowledge," says Menzel. That enthusiasm is apparently infectious, for Menzel now believes "We face the possibility of humans melding with robots. They can replace our body parts. And we can take our intelligence and program it into a robot and have creatures equal or superior to humans." Previous collaborations by the duo include *Women in the Material World* (1996) and *Man Eating Bugs: The Art and Science of Eating Insects* (1998).



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Brief Summary (For Full Prescribing Information, see package insert).

INDICATIONS AND USAGE: CLARITIN is indicated for the relief of nasal and non-nasal symptoms of seasonal allergic rhinitis and for the treatment of chronic idiopathic urticaria in patients 6 years of age or older. **CONTRAINDICATIONS:** CLARITIN is contraindicated in patients who are hypersensitive to this medication or to any of its ingredients. **PRECAUTIONS:** **General:** Patients with liver impairment or renal insufficiency (GFR < 30 mL/min) should be given a lower initial dose (10 mg every other day). (See **CLINICAL PHARMACOLOGY: Special Populations.**) **Drug Interactions:** Loratadine (10 mg once daily) has been coadministered with therapeutic doses of erythromycin, cimetidine, and ketoconazole in controlled clinical pharmacology studies in adult volunteers. Although increased plasma concentrations (AUC 0-24 hrs) of loratadine and/or descarboethoxyloratadine were observed following coadministration of loratadine with each of these drugs in normal volunteers (n = 24 in each study), there were no clinically relevant changes in the safety profile of loratadine, as assessed by electrocardiographic parameters, clinical laboratory tests, vital signs, and adverse events. There were no significant effects on QT_i intervals, and no reports of sedation or syncope. No effects on plasma concentrations of cimetidine or ketoconazole were observed. Plasma concentrations (AUC 0-24 hrs) of erythromycin decreased 15% with coadministration of loratadine relative to that observed with erythromycin alone. The clinical relevance of this difference is unknown. Effects on plasma concentrations (AUC 0-24 hrs) of loratadine and descarboethoxyloratadine after 10 days of coadministration (loratadine 10 mg) in normal volunteers were as follows: with erythromycin (500 mg Q8h), loratadine +40%, descarboethoxyloratadine +46%; with cimetidine (300 mg QID), loratadine +103%, descarboethoxyloratadine +6%; with ketoconazole (200 mg Q12h), loratadine +307%, descarboethoxyloratadine +73%. There does not appear to be an increase in adverse events in subjects who received oral contraceptives and loratadine. **Carcinogenesis, Mutagenesis, and Impairment of Fertility:** In an 18-month carcinogenicity study in mice and a 2-year study in rats, loratadine was administered in the diet at doses up to 40 mg/kg (mice) and 25 mg/kg (rats). In the carcinogenicity studies, pharmacokinetic assessments were carried out to determine animal exposure to the drug. AUC data demonstrated that the exposure of mice given 40 mg/kg of loratadine was 3.6 (loratadine) and 18 (descarboethoxyloratadine) times higher than in humans given the maximum recommended daily oral dose. Exposure of rats given 25 mg/kg of loratadine was 28 (loratadine) and 67 (descarboethoxyloratadine) times higher than in humans given the maximum recommended daily oral dose. Male mice given 40 mg/kg had a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) than concurrent controls. In rats, a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) was observed in males given 10 mg/kg and males and females given 25 mg/kg. The clinical significance of these findings during long-term use of CLARITIN is not known. In mutagenicity studies, there was no evidence of mutagenic potential in reverse (Ames) or forward point mutation (CHO-HGPRT) assays, or in the assay for DNA damage (rat primary hepatocyte unscheduled DNA assay) or in two assays for chromosomal aberrations (human peripheral blood lymphocyte clastogenesis assay and the mouse bone marrow erythrocyte micronucleus assay). In the mouse lymphoma assay, a positive finding occurred in the nonactivated but not the activated phase of the study. Decreased fertility in male rats, shown by lower female conception rates, occurred at an oral dose of 64 mg/kg (approximately 50 times the maximum recommended human daily oral dose on a mg/m² basis) and was reversible with cessation of dosing. Loratadine had no effect on male or female fertility or reproduction in the rat at an oral dose of approximately 24 mg/kg (approximately 20 times the maximum recommended human daily oral dose on a mg/m² basis). **Pregnancy Category B:** There was no evidence of animal teratogenicity in studies performed in rats and rabbits at oral doses up to 96 mg/kg (approximately 75 times and 150 times, respectively, the maximum recommended human daily oral dose on a mg/m² basis). There are, however, no adequate and well-controlled studies in pregnant women. Because animal reproduction studies are not always predictive of human response, CLARITIN should be used during pregnancy only if clearly needed. **Nursing Mothers:** Loratadine and its metabolite, descarboethoxyloratadine, pass easily into breast milk and achieve concentrations that are equivalent to plasma levels with an AUC_{0-12h}/AUC_{0-24h} ratio of 1.17 and 0.85 for loratadine and descarboethoxyloratadine, respectively. Following a single oral dose of 40 mg, a small amount of loratadine and descarboethoxyloratadine was excreted into the breast milk (approximately 0.03% of 40 mg over 48 hours). A decision should be made whether to discontinue nursing or to discontinue the drug, taking into account the importance of the drug to the mother. Caution should be exercised when CLARITIN is administered to a nursing woman. **Pediatric Use:** The safety of CLARITIN Syrup at a daily dose of 10 mg has been demonstrated in 188 pediatric patients 6-12 years of age in placebo-controlled 2-week trials. The effectiveness of CLARITIN for the treatment of seasonal allergic rhinitis and chronic idiopathic urticaria in this pediatric age group is based on an extrapolation of the demonstrated efficacy of CLARITIN in adults in these conditions and the likelihood that the disease course, pathophysiology, and the drug's effect are substantially similar to that of the adults. The recommended dose for the pediatric population is based on cross-study comparison of the pharmacokinetics of CLARITIN in adults and pediatric subjects and on the safety profile of loratadine in both adults and pediatric patients at doses equal to or higher than the recommended doses. The safety and effectiveness of CLARITIN in pediatric patients under 6 years of age have not been established. **ADVERSE REACTIONS: CLARITIN Tablets:** Approximately 90,000 patients, aged 12 and older, received CLARITIN Tablets 10 mg once daily in controlled and uncontrolled studies. Placebo-controlled clinical trials at the recommended dose of 10 mg once a day varied from 2 weeks' to 6 months' duration. The rate of premature withdrawal from these trials was approximately 2% in both the treated and placebo groups. The reported adverse events with an incidence of more than 2% in placebo-controlled allergic rhinitis clinical trials in patients 12 years of age and older with loratadine 10 mg OD (n=1926), placebo (n=2545), clemastine 1 mg BID (n=536), and terfenadine 60 mg BID (n=684), respectively, were: headache (12%, 11%, 8%, and 8%); somnolence (8%, 6%, 22%, and 9%); fatigue (4%, 3%, 10%, and 2%); and dry mouth (3%, 2%, 4%, and 3%). Adverse events reported in placebo-controlled chronic idiopathic urticaria trials were similar to those reported in allergic rhinitis studies. Adverse event rates did not appear to differ significantly based on age, sex, or race, although the number of nonwhite subjects was relatively small. **CLARITIN REDITABS (loratadine rapidly-disintegrating tablets):** Approximately 500 patients received CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) in controlled clinical trials of 2 weeks' duration. In these studies, adverse events were similar in type and frequency to those seen with CLARITIN Tablets and placebo. Administration of CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) did not result in an increased reporting frequency of mouth or tongue irritation. **CLARITIN Syrup:** Approximately 300 pediatric patients 6 to 12 years of age received 10 mg loratadine once daily in controlled clinical trials for a period of 8-15 days. Among these, 188 children were treated with 10 mg loratadine syrup once daily in placebo-controlled trials. Adverse events in these pediatric patients were observed to occur with type and frequency similar to those seen in the adult population. The rate of premature discontinuance due to adverse events among pediatric patients receiving loratadine 10 mg daily was less than 1%. The reported adverse events occurring with a frequency of ≥ 2% in loratadine syrup-treated patients (6-12 years old) in placebo-controlled trials, and more frequently than in the placebo group, with loratadine 10 mg OD (n=188), placebo (n=262), and chlorpheniramine 2-4 mg BID/TID (n=170) were, respectively: nervousness (4%, 2%, and 2%); wheezing (4%, 2%, and 5%); fatigue (3%, 2%, and 5%); hyperkinesia (3%, 1%, and 1%); abdominal pain (2%, 0%, and 0%); conjunctivitis (2%, <1%, and 1%); dysphonia (2%, <1%, and 0%); malaise (2%, 0%, and 1%); and upper respiratory tract infection (2%, <1%, and 0%). In addition to those adverse events reported above (≥ 2%), the following adverse events have been reported in at least one patient in CLARITIN clinical trials in adult and pediatric patients: **Autonomic Nervous System:** Altered lacrimation, altered salivation, flushing, hypoesthesia, impotence, increased sweating, thirst. **Body As A Whole:** Angioneurotic edema, asthenia, back pain, blurred vision, chest pain, earache, eye pain, fever, leg cramps, malaise, rigors, tinnitus, viral infection, weight gain. **Cardiovascular System:** Hypertension, hypotension, palpitations, supraventricular tachyarrhythmias, syncope, tachycardia. **Central and Peripheral Nervous System:** Blepharospasm, dizziness, dysphonia, hypertonia, migraine, paresthesia, tremor, vertigo. **Gastrointestinal System:** Altered taste, anorexia, constipation, diarrhea, dyspepsia, flatulence, gastritis, hiccup, increased appetite, nausea, stomatitis, toothache, vomiting. **Musculoskeletal System:** Arthralgia, myalgia. **Psychiatric:** Agitation, amnesia, anxiety, confusion, decreased libido, depression, impaired concentration, insomnia, irritability, paranoia. **Reproductive System:** Breast pain, dysmenorrhea, menorrhagia, vaginitis. **Respiratory System:** Bronchitis, bronchospasm, coughing, dyspnea, epistaxis, laryngitis, nasal dryness, pharyngitis, sinusitis, sneezing. **Skin and Appendages:** Dermatitis, dry hair, dry skin, photosensitivity reaction, pruritus, purpura, rash, urticaria. **Urinary System:** Altered micturition, urinary discoloration, urinary incontinence, urinary retention. In addition, the following spontaneous adverse events have been reported rarely during the marketing of loratadine: abnormal hepatic function, including jaundice, hepatitis, and hepatic necrosis; alopecia; anaphylaxis; breast enlargement; erythema multiforme; peripheral edema; and seizures. **OVERDOSAGE:** In adults, somnolence, tachycardia, and headache have been reported with overdoses greater than 10 mg with the Tablet formulation (40 to 180 mg). Extrapyramidal signs and palpitations have been reported in children with overdoses of greater than 10 mg of CLARITIN Syrup. In the event of overdose, general symptomatic and supportive measures should be instituted promptly and maintained for as long as necessary. Treatment of overdose would reasonably consist of emesis (ipecac syrup), except in patients with impaired consciousness, followed by the administration of activated charcoal to absorb any remaining drug. If vomiting is unsuccessful, or contraindicated, gastric lavage should be performed with normal saline. Saline cathartics may also be of value for rapid dilution of bowel contents. Loratadine is not eliminated by hemodialysis. It is not known if loratadine is eliminated by peritoneal dialysis. No deaths occurred at oral doses up to 5000 mg/kg in rats and mice (greater than 2400 and 1200 times, respectively, the maximum recommended human daily oral dose on a mg/m² basis). Single oral doses of loratadine showed no effects in rats, mice, and monkeys at doses as high as 10 times the maximum recommended human daily oral dose on a mg/m² basis.

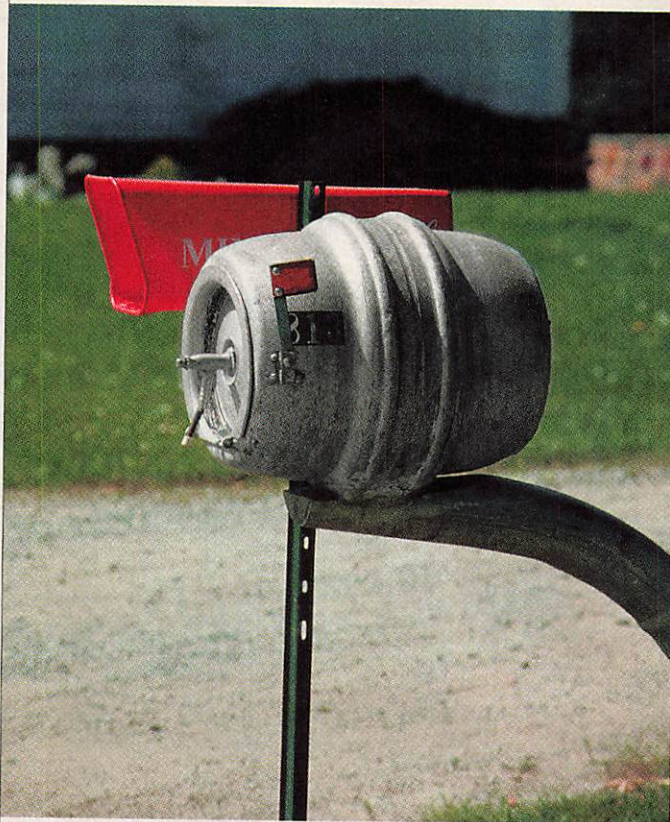
Schering

Schering Corporation
Kenilworth, NJ 07033 USA
CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) are manufactured by Schering Corporation by Scherer DDS, England.

U.S. Patent Nos. 4,282,233 and 4,371,516.

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LETTERS



THEY DO MAKE THEM LIKE THEY USED TO, SORT OF

I must clarify at least one technical misrepresentation of the Cremona puzzle, as presented in "Stradivari's Secret" [July]. At the top of the list of critical ingredients is the filler that penetrates into the wood of the white violin before the varnish is applied. The composition of the filler is the major determinant of tone quality. Its omission may annoy the savants and leave others unenlightened.

As for the tenor of the article, I must correct the impression that I am making exclusive claims. Many violin makers can occasionally make violins as good as the average Stradivarius, and they may even apply the same materials I do. What separates my work from that of the best violin makers is a better understanding of materials science: Knowing not only what works, but why. I have offered an attractive rationale in the form of educated guesses, which is being tested worldwide. There is no such thing as a definitive solution.

JOSEPH NAGYVARY

College Station, Texas

Michael Lemonick responds: As a scientist, Nagyvary is naturally sensitive to the idea that he may be perceived as making outright claims where he's actually making reasonable inferences. In this case, I think the article makes it clear that he's doing the latter.

THE SPRAYING NEXT TIME

As a Californian whose community has been sprayed aerially with malathion, I read "Silent Summer" [July] with interest. However, I am disappointed with your East Coast myopia, as if malathion has been used only in the East, and only when it is used in New York does it rate the attention of *Discover*.

LOWELL GEORGIA CORBIS

In 1983 to 1984, malathion was aerially sprayed over populated areas of Santa Clara County in Northern California, and in 1989 to 1990 it was aerially sprayed over much of densely populated Greater Los Angeles over a six-month period. Although the Santa Clara victims rose to protest, they largely suffered in silence and without redress.

When the victims in Los Angeles struck back, however, the groundwork was laid for the acquisition of the knowledge upon which you based your article. Virtually every city that was sprayed sued the state and USDA to stop the spraying. Neighborhood protest groups organized into umbrella organizations that function to this day.

When other communities were later sprayed, Southern California anti-malathion activists provided vast bodies of knowledge, established legal precedents, and offered organizational aids. In spite of subsequent medfly sightings in Los Angeles and in spite of the USDA's reservation of the right to do so again, aerial spraying of malathion has not resumed in Los Angeles.

If the East Coast populations insist that "mild neurotoxins" (your oxymoron) not be

an option for pest control, I assure you that the authorities will find safer alternative means of control.

RICHARD SIGLER
Los Angeles

BEAUTY AT 70,000 FEET

I enjoyed your article about the aurora borealis ["Seeing the Light," July]. During 34 years as an Air Force pilot, I have been privileged to witness many outstanding views of this phenomenon while flying over the Arctic. However, there were none like those I experienced in the fall of 1962 while flying the U-2 high-altitude reconnaissance plane on night missions out of England, proceeding around the northern perimeter of Norway. At altitudes of more than 70,000 feet, I felt like I was immersed in the most beautiful, flowing light show I'd ever seen. It was terribly vertigo-inducing, and if it hadn't been for good autopilot, I would have been hard-pressed to fly the plane. As it was, I had to periodically force myself back onto the instrument display to keep my head on straight. It was a sight my fellow pilots and I saw many times during

such missions. Too bad we couldn't carry cameras in the cockpits with us.

PATRICK HALLORAN
Colorado Springs, Colorado

QUEENS AT WAR—UNINTENTIONALLY

In the solution to Problem 1 in "Queens at Peace" [Bogglers, July], the white queen second from the right at the bottom of the board should have been placed on the white square directly above.

HELP FROM DISCOVER

Letters: Address letters to *Discover*, 114 Fifth Avenue, New York, NY 10011-5690; e-mail to editorial@discover.com. Include the writer's full name, address, and daytime phone number. Letters may be edited for length and clarity, and may be published in the magazine or on its Web site. Due to the volume of mail we receive, we cannot respond to every letter. **Customer service/subscription inquiries/back issues:** For questions about your subscription or obtaining back issues, call toll-free 800-829-9132; outside U.S., 515-246-6952. Or write to *Discover*, P.O. Box 37283, Boone, IA 50037-0283. **Submissions:** We cannot be held responsible for unsolicited manuscripts or materials of any kind. **Internet:** *Discover* Web site (www.discover.com). **Note to subscribers:** *Discover* occasionally allows selected companies to send mail to our subscribers. If you would rather not receive these mailings, please send your current mailing label or an exact copy to *Discover*, P.O. Box 37283, Boone, IA 50037-0283.

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Why would the real Milky Way cause tooth decay?

Could you drink water on Mars?

How can a plant detect extraterrestrial life?

How many sentients are on the Jedi Council?

What x-vehicle first broke the sound barrier?

What planet's day is longer than its year?

Why is NASA launching laser-propelled satellites into space?

Space news

Launches and missions

Space videos/pictures

The search for life

Sci-Fi

Space Technology

Space in films and TV

Space games

SpaceKids.com

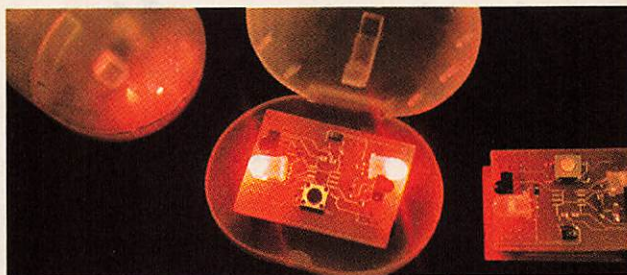
Starry Night

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The Crack Kid Myth



BEAM ME UP, BARBIE

Barbara Barry is dismayed by the technological toys marketed to girls: makeover software, fake pink laptops designed for Barbie-lovers, and the like. Barry, an artist based at MIT's Media Lab, thinks she can do better. She created StoryBeads, wearable computers that can be strung together into a necklace. Each unit can store both images and text—snapshots from a digital camera, for instance, or a poem downloaded from a home PC. Infrared transmitters on the StoryBeads can beam data back and forth, while a small screen on the central “amulet” displays the collected words and pictures. Barry hopes girls will trade the beads or thread them together to create ever-changing stories, and look inside to see how they work. “This will lead girls to see that technology is a flexible thing that can be useful to them,” says Barry. —*Josie Glausiusz*



More than 30 states have filed charges against women for taking illegal drugs during pregnancy. In 1997, for instance, South Carolina's Supreme Court ruled that women who use drugs during pregnancy can be prosecuted for child abuse. The vast majority of women targeted under this policy are crack cocaine users. But a new study

conducted at the University of Florida suggests the laws are as misguided as they are harsh. Children born to cocaine-addicted mothers are no more likely than other kids from similar backgrounds to have significant behavioral problems during their first three years.

Psychologist Fonda Davis Eyler and pediatrician Marylou

Behnke studied 300 children from poor families with similar racial backgrounds. Half of the kids had been exposed to cocaine in the womb, half had not. The researchers asked the parents or guardians to answer detailed questions about their children's behavior and temperament. There were no significant differences between the

two groups, although both sets of children showed more behavioral problems than average—a finding that Eyler and Behnke attribute to poverty and bad living conditions. “There's not a strong effect of cocaine on misconduct or behavior problems in these children,” says Eyler. “We can have a lot more hope about their future.”

Still, she and Behnke agree that questionnaires completed by caretakers or family members may give subjective results. Psychologist Barbara Strupp of Cornell hoped to avoid such ambiguities with a laboratory test. She injected rats with cocaine during pregnancy and then studied their offspring. The rat young displayed no memory deficits or social abnormalities, although they did have difficulty staying attentive to tasks when distracted. “In the early 1990s, major magazines ran cover stories on crack kids, but these reports were not based on scientific evidence. Despite popular belief that there are lasting and devastating effects of prenatal cocaine exposure, that just hasn't been the case,” Strupp says. —*Josie Glausiusz*

A Broccoli-Eating Croc?

It's not quite a flying pig, but paleontologist Greg Buckley at Roosevelt University in Illinois and his colleagues recently unearthed something nearly as improbable: the skull of an ancient vegetarian crocodile.

The strange-looking fossil, extracted from 70-million-year-

their dinosaur relatives. The remains suggest a full-grown Simosuchus was about three feet long. Its thickened head and neck were probably used for burrowing, not attacking.

"We had no idea that anything like this existed," says Buckley. He suspects intense



old rocks in Madagascar, has a short pug nose and a tall head. The most unusual feature of the new species, called Simosuchus, is its multi-cusped teeth, which resemble those of herbivorous dinosaurs like ankylosaurs and stegosaurs. Only when the researchers found an intact skull did they spot the key anatomic features—including bony plates in the skin, called osteoderms—that distinguish crocodiles from

competition forced Simosuchus to give up the carnivorous ways of normal crocodiles. The fossil also offers a puzzle for geologists. It appears related to Uruguaysuchus, an extinct line of crocodiles found in Uruguay. Buckley thinks this implies that a land bridge connected Madagascar and South America 80 million years ago, long after the young Atlantic Ocean allegedly separated the two landmasses.

Science Myth

Myth: There are seven colors in the rainbow.

Fact: There are as many colors in the rainbow as the eye can see. Red and blue are prominent because they mark the edges of the bow, and yellow-green usually stands out because the sun is brightest in that color. But rainbows, like sunlight, contain a continuous spectrum that does not neatly divide into red, orange, yellow, green, blue, indigo, and violet.

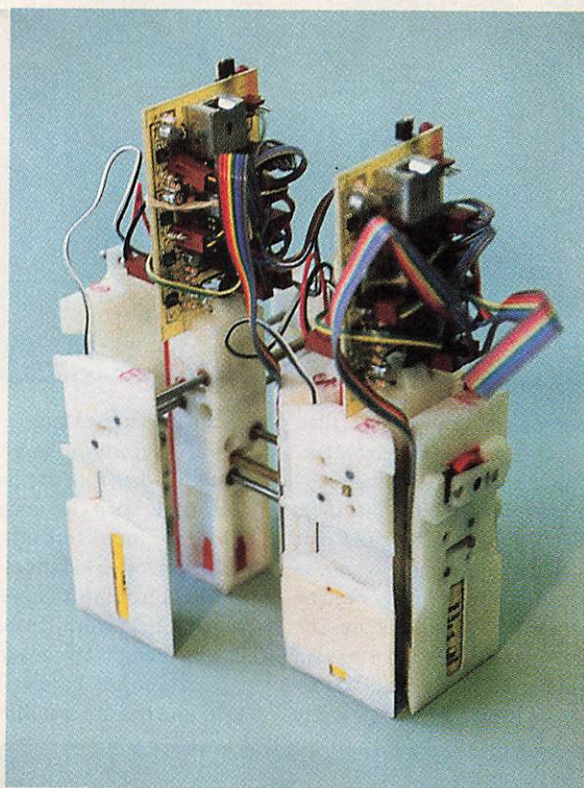
"When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong"

—Arthur C. Clarke

ROBOT WATCH: ATOMIC BONDS

A single living cell cannot do much, but a bunch of them linked together can become a swimming shark, a running gazelle, or a flying falcon. Daniela Rus of Dartmouth College and her former student Marsette Vona, now at MIT, are building modular robots that mirror that kind of flexibility. Each module consists of a cube-shaped unit, called an atom, equipped with its own battery and sensors. The atoms can expand from two to four inches wide and can attach to one another. When the atoms lock together, the robot can scoot along like an inchworm or rearrange its atoms into another shape better suited to the task at hand, whether it involves movement, grasping, or sensing.

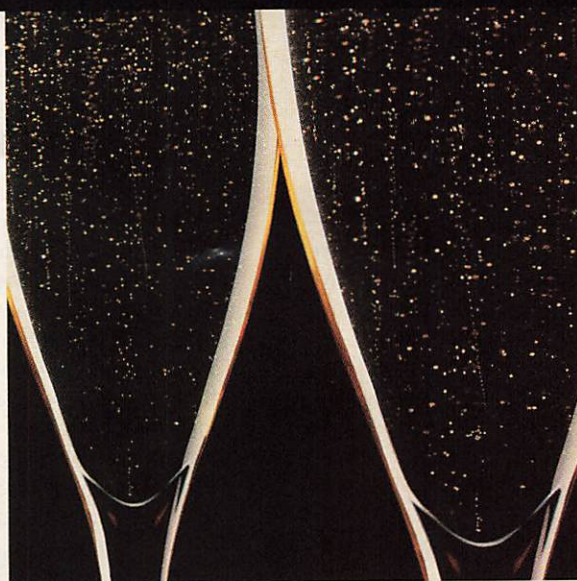
Rus hopes to eventually build robots from thousands of miniaturized atoms made out of microelectromechanical devices, each hardly bigger than the biological cells it mimics. These future versions could be used to survey remote or uninhabitable landscapes or to create self-assembling structures in space. They could form endlessly readjustable conveyor belts in factories or computerized "modeling clay" to display architects' computer renderings of possible new buildings. They might even apply their protean ways to tend to your comfort. "The robots could create smart furniture that would be the ultimate customization for the home," Rus says. —Fenella Saunders



LEFT: GREGORY BUCKLEY; RIGHT: JOSEPH MEHLING/DARTMOUTH COLLEGE

dreams made real.

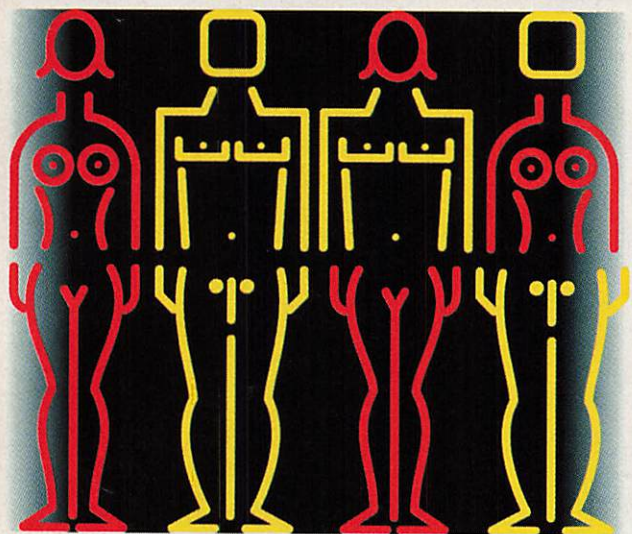
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Sexing the Genome

Evolution is ultimately a battle of the sexes. Fathers favor large offspring with a better chance of survival, so mammalian males evolved genes that promote growth. Hefty young are a drain on the mother, so females evolved competing sets of anti-growth genes.

Biologists had thought this genetic monkey-wrenching, called imprinting, first evolved in placental mammals, which invest heavily in gestating their young. But molecular biologist

Randy Jirtle of Duke University and his colleagues found that marsupials also have imprinted genes. "That means that the battle is moved back to at least 100 million years ago," Jirtle says.

Imprinted genes are linked with cancer, as well as autism and other behavioral disorders. "The closer we get to understanding imprinting, the better chance we have of finding ways to loosen the imprinted genes through chemical means," Jirtle says. —Kathy A. Svitil

ASK THE WIZARD» Would an unprotected body decay in space?

JOSHUA CULLEY, OLYMPIA, WASHINGTON

Russell B. Rayman, the executive director of the Aerospace Medical Association in Alexandria, Virginia, responds:

A body drifting in space would probably be in a desiccated state similar to that of the mummified bodies people sometimes find in the desert. In space there is no humidity and no microorganisms which, in combination, cause decomposition of human tissue on Earth. The very low temperatures in space would provide further protection for tissue—unless the body were close to the sun, in which case the intense radiation would incinerate it. Therefore, an unsuited human body in space would likely remain recognizable for a long while, although there would be extreme drying because moisture from the body would escape readily into the vacuum. Over time, it is likely that micro-meteors would strike the body. A rock the size of a grain of sand would hit with the force of a bullet; enough hits and the body would disintegrate. Another potential degrading factor is exposure to high levels of radiation and energetic subatomic particles. In this case we do not know what the long-term effects would be.

"The danger from computers is not that they will eventually get as smart as men, but that we will meanwhile agree to meet them halfway"

—Bernard Avishai

RED WATERWORLD

The long search for water on Mars—which could greatly boost the prospects of finding life or fossils there—is suddenly looking more promising. Recent images from the *Mars Global Surveyor* hint that water may still flow from underground reservoirs. And now two studies of meteorites sitting here on Earth offer a peek into the Martian past, when the planet's surface may have been covered with extensive, salty seas.

Carleton Moore, a chemist at Arizona State University, and his colleagues bored into the 1.2-billion-year-old Nakhla meteorite, a fragment of Mars that slammed into Egypt in 1911. Inside, they found water-soluble salts, including sodium chloride and calcium. "The simplest explanation is that they came from seawater that seeped into cracks in the rock and then evaporated," says Moore. The salts closely resemble those in Earth's oceans, he reports, but with a twist: "The water in the Martian meteorite has more calcium. We think that's because the calcium in our seas is removed by organisms to make shells."

In a complementary study, cosmochemist Laurie Leshin, also of ASU, examined another, 300-million-year-old Mars meteorite. Leshin measured the concentrations of deuterium, a heavy version of hydrogen, in the rock's crystals. As water from Mars escapes into space, deuterium is more likely than ordinary hydrogen to get left behind. According to Leshin's analysis, Mars started out with much more deuterium than previously thought. As a result, she thinks scientists need to double or triple their estimates of the amount of water still lurking in the planet's crust. All they need now is a working NASA spacecraft to look for that water firsthand—something that will happen around 2003, if all goes well. —Kathy A. Svitil

STRANGE EROSION STREAKS IN THIS MARTIAN CRATER HAVE CONVINCED SCIENTISTS THAT WATER FLOWED ON MARS RECENTLY—MAYBE A MILLION YEARS AGO, MAYBE YESTERDAY.



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September 8 435th anniversary of North America's first town of European origin, at present-day St. Augustine, Florida.

September 12 60th anniversary of the discovery of the Lascaux grotto, site of one of the most outstanding displays of prehistoric cave art.

Awards: Nine scientists are among the 25 recipients of this year's MacArthur Foundation Awards, the so-called genius awards of \$500,000. They include: Paleontologist Christopher Beard of the Carnegie Museum of Natural History, whose work suggests early anthropoids hail from Asia, not Africa; physicist Hideo Mabuchi of Caltech (below), who studies the evolution



of quantum systems; geochemist Daniel Schrag of Harvard, who investigates ancient climates; neuroscientist Gina Turrigiano of Brandeis University, who studies how brain cells respond to change; and computer scientist Erik Winfree of Caltech, who is developing DNA computers. **Died:** Surgeon Keith Reemtsma, 74, on June 23. In 1964, Reemtsma, a pioneer of cross-species transplants, put a chimpanzee kidney into an ailing woman. She survived an additional nine months.



THE BALLOON OF THE FUTURE TAKES SHAPE AT NASA'S WALLOPS FLIGHT FACILITY, OFF THE COAST OF VIRGINIA.

Flying Pumpkins

To astronomers and earth scientists, balloons aren't toys; they're serious tools that allow a good view without the cost of launching a satellite. But in flight, research balloons must vent helium each time they are heated by the midday sun. They also bob up and down annoyingly and stay aloft no more than a week or two. So NASA engineers have created a pump-

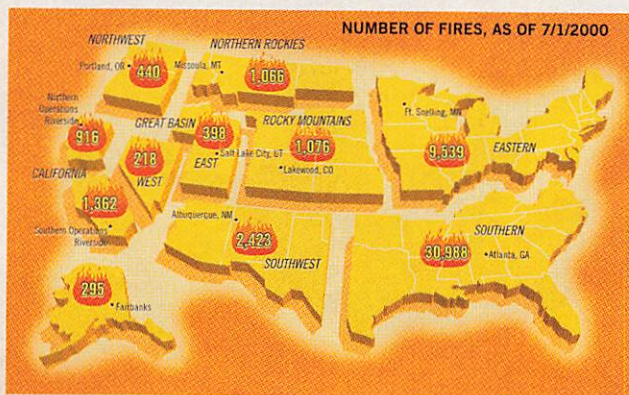
kin-shaped floater that can hang steadily at 115,000 feet and stay there for 100 days.

The ultra-long-duration balloon is made of a lightweight three-ply polymer, about as thick as plastic food wrap. The polymer can withstand high pressures as the balloon heats and cools over the course of a day, so it can stay completely sealed. No gas escapes. Fiber

tendons, which form the lobes of the pumpkin, bear the weight of the payload and eliminate strain on the thin skin.

In a test run last June, a scaled-down pumpkin balloon flew for 30 hours without losing gas or altitude. The full-sized version, now under construction, will be the size of a football stadium and able to haul 3,500 pounds of payload—including, perhaps, telescopes to rival the Hubble Space Telescope. Its test flight is set for January 2001. —Kathy A. Svitil

THE BIG BURN BY MID-JULY, MORE THAN 50,000 WILDFIRES HAD BURNED THROUGH 2.3 MILLION ACRES IN THE UNITED STATES—NEARLY A MILLION ACRES MORE THAN THE TEN-YEAR AVERAGE. THE MAIN CULPRIT: LA NIÑA—THE REVERSE WEATHER PATTERN OF EL NIÑO—LED TO DRY AND WARM WINTERS IN THE SOUTH. IN THE WEST, SPRING AND SUMMER RAINFALL ALSO FELL WELL BELOW NORMAL.



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DON'T BE SCARED—THIS AUSTRALIAN FUNNEL-WEB SPIDER MAY HELP PROTECT CROPS FROM PESTS WITHOUT HARMING OTHER ANIMALS.

Elixir of Spider Spit

Over the centuries, spider extracts have been used as a folk treatment for everything from bubonic plague to bleeding gums, with generally dubious results. But recent experiments show scientists are having rather better success in tapping the power of arachnid alchemy.

At the State University of New York at Buffalo, biophysicists Fred Sachs and Thomas Suchyna discovered that a protein in the venom of the Chile Rose tarantula could prevent deaths from heart attacks. The protein blocks the action of stretch-activated channels, pores in cell membranes that respond to touch, muscle contraction, and blood pressure. During a heart attack, these channels open and unleash chemical signals that disrupt the rhythm of the heart. Often the resulting fibrillation—not the initial attack—is what kills. The spider venom protein might help prevent this lethal fibrillation.

Meanwhile, at the University of Connecticut, biochemist Glenn King is studying chemicals from the Australian funnel-web spider. His aim is not to heal but to kill—insects, that is. He's searching for alternatives to current pesticides, which can linger in soil and poison animals. King found a component

in the funnel-web spider's venom that is deadly to cockroaches, crickets, and fruit-flies, but harmless to lab rats. Eventually he aims to create an engineered virus that produces its own version of the spider venom and infects only specific pests, such as the cotton bollworm. "I'd like to stop the accidental killing of species that aren't the targeted pest, including other insects, birds, and fish," says King. —*Josie Glausiusz*



A KERNEL OF STYLE

Ecology-minded folks have a new way to wear their concerns on their sleeves. Cargill Dow, a polymer company in Nebraska, has found a way to spin clothing fibers out of cornstarch. Right now they're using starch from the kernels, but the process could someday turn agricultural waste into crisp polo shirts.

Through a mix of fermentation and chemical processing, Cargill Dow transforms cornstarch into lactic acid and then into a long, elastic molecule. The resulting material is as strong and resilient as regular plastics. It can be molded or spun into a silky, breathable fabric. "Our raw material comes from sunlight and carbon dioxide in the atmosphere, whereas in any other plastic, that raw material comes from the hydrocarbons out of the ground," says Pat Gruber, Cargill Dow's vice president of technology. "Overall we can use 20 to 50 percent less fossil resources in manufacturing our product." Corn-based food containers and clothing have hit stores in Europe and Japan, where one eco-friendly designer created a wedding dress from the biodegradable fiber.

—*Fenella Saunders*

SEPTEMBER 8

Space shuttle *Atlantis*, carrying components for the International Space Station, from the Kennedy Space Center in Florida.

SEPTEMBER 18

Thuraya 1A comsat, on a Zenit-3SL rocket, from the *Odyssey* mobile sea-launch platform in the Pacific Ocean.

SEPTEMBER 21

Progress M1 module with supplies for the Space Station, on a Soyuz-U rocket from the Baikonur Cosmodrome, Kazakhstan.

SEPTEMBER 28

Minuteman III missile test, from Vandenberg Air Force Base, California.

WHAT'S GOING UP NMOD 9N109 S.1VHM

SEPTEMBER 1-30

Marine archaeologists from Ireland's University of Ulster, off the coast of Kenya, to conduct surveys of a 17th-century port.

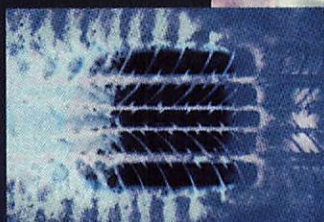
SEPTEMBER 4-12

Biologists from the Mingen Island Cetacean Study, off the coast of Quebec, to study the effects of polluted waters on various whale species.

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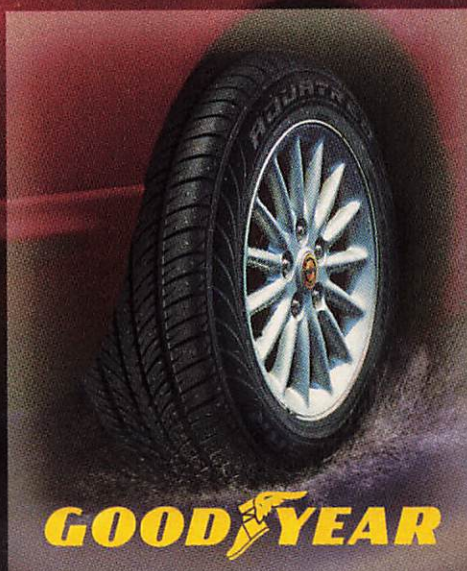
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The Wetlands That Almost Disappeared.

In southern Louisiana, a vital wildlife breeding ground was endangered. Freshwater wetlands



were vanishing. Leveeing along the Mississippi River had reduced the influx of fresh water and silt. But

then, people working nearby partnered with the Fish and Wildlife Service to carve channels into the levees. Hundreds of acres in the Delta National Wildlife Refuge were restored. And so was nature's glorious nursery.

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W. NELSON



MASTER OF THE MICRO WORLD

If it's tiny and electronic, Mark Reed is probably tinkering with it. In 1987 he invented quantum dots, microscopic boxes that contain just a handful of free electrons, which could form the basis of a radically miniaturized computer memory. Now Reed, an electrical engineer at Yale University, is a leader in the search for a successor to the silicon chip. He is developing novel techniques for assembling switches, memory, and other computer components, molecule by molecule. The work is progressing so quickly that Reed co-founded Molecular Electronics Corp. to commercialize the technology. He recently shared his vision of molecular computing

with *Discover* Associate Editor Fenella Saunders.

How small can computers get?

A computer today is a big box that sits on your desk or lap, but the actual part that's doing the calculations is already just a small bunch of chips. The rest of it is displays and keyboards. So I don't think it's a question of how small, it's a question of how powerful. As we're able to increase the capability of computers, we can start to put intelligence in a lot of things that interact with us through the day. I see a revolution over the next few decades. This amazing amount of computer power will be transparent to us but will extend through many things in our lives.

How do you use molecular electronics to build a computer?

The thing you need in a computer system is something to control the flow of current. By doing that you create logic and eventually memory. Think about it as configurations of light switches. We've shown that molecules can act as switches. We have molecules where, under certain conditions, the current flows through and, under other conditions, the current doesn't flow through. Now we just have to figure out how to put it all together.

How can you manufacture such tiny switches?

Fabricating devices gets increasingly hard the smaller you make them. If you can find a way to use some natural processes to control the fabrication, that's a tremendous advantage. Our strategy has been to utilize self-assembly, which is just a chemical reaction that gets the molecules to stick where you want them. We don't see a limit to how small we can make devices until we reach the atomic scale.

Will we ever be able to build quantum computers, devices that operate at the subatomic scale?

I don't think there are very good ideas out there yet on how to make a quantum computer. But if we do find the right idea, oh, it's going to be phenomenal.

Is it really possible to predict where the technology is headed?

In 1950, it would have been a very obvious extension to say that in the year 2000 you'd have a nuclear-powered toaster. In the 1970s, few people predicted having an Internet. People think very linearly, but it is the right-angle turns that really are the most interesting. Some of the uses we are going to find for these electronics systems—I think even our wildest imaginings might be too conservative.

What excites you most?

Controlling nature, one atom at a time, and being able to get it to dance the way you want it to.

RING OF FIRE

No, Earth is not being incinerated. The orange cloud enveloping the planet in this image is sunlight scattering off helium ions in the plasmasphere—the extremely rarefied, electrically charged bit of our atmosphere that extends 12,000 miles into space. This infernal view was beamed back by NASA's Imager for Magnetopause to Aurora Global Exploration (IMAGE) satellite, which monitors what happens when solar storms reach Earth.

"We had almost no idea of what the plasmasphere looked like," says James Burch of the Southwest Research Institute in San Antonio, the principal investigator on IMAGE. "We thought it had smooth edges and long tails that extended out into space from the dusk side, but it is actually circular." The scalloped fringes of plasma



on the upper left formed after a small magnetic disturbance from the sun passed Earth. "We don't really know why they are there," Burch says, but they appear to form before a full-on solar squall that could disrupt power and communications. Burch and the rest of the IMAGE team hope their satellite will allow scientists to track space storms, much as weather satellites now monitor thunderstorms.

—Kathy A. Svitil



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Duke Ellington It Don't Mean A Thing (If It Ain't Got That Swing) 1178
Coleman Hawkins Someone To Watch Over Me 1179
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The Measure of Man

Computers are getting to know what you look like—perhaps too well

IN 1989, FEELING FLUSH WITH cash from my first book contract, I bought a voiceprint lock for \$1,500 and had it installed on the front door of my condominium. The device was the size of a shoe box, with a keypad on the front and a four-digit red LED readout. To get into my house I would simply enter my code (9#) and say my password ("airplane"). A moment later, the door would unlock. Overall, the system worked pretty well, but it wouldn't let me into my house during a loud thunderstorm or, ironically, when an airplane was passing overhead. When I sold the condo, the new owners painted over the voiceprint reader and installed a more familiar, key-hole lock. They weren't quite ready for the technology, and the technology wasn't quite ready for them.

A decade later, computerized biometrics—systems that read your body measurements or patterns such as fingerprints, voiceprints, iris prints, or facial features—has finally come of age. The U.S. Army is building a huge biometric database intended to simplify everything from salary payments to military security. Banks are experimenting with iris scanners as a way to replace ATM cards and numerical pass codes. A prototype cell phone incorporates a thumbprint reader to prevent fraudulent use. And security companies are developing low-cost devices that could provide more privacy for your home PC. As a result, the \$60 million commercial biometrics market is expected to grow tenfold in the next three years.



Fingerprint scanners, such as this one made by Recognition Systems, now record attendance and unlock doors without keys, cards, or codes.

Fingerprints, which are by far the best-established biometric markers, have thoroughly proven their worth in the world of law enforcement. More than a hundred years ago, police in Argentina began recording fingerprints left at a crime scene to identify suspects. The idea quickly spread. Throughout the 20th century, U.S. police departments and the FBI compiled "10-print cards" from suspects and lifted samples of fingerprints from crime scenes. But as these files grew larger and larger they became less and less useful, because searching for a match was manual. By the mid-1980s it would have taken a single worker more than 33 years to search the U.S. Department of Justice's

300,000 fingerprint cards for a match, according to a 1987 department report.

Computerized fingerprint systems fundamentally changed the rules. As police departments scanned fingerprint cards and latent prints from crime scenes into their computers, the computers rapidly found matches and solved crimes that had been given up as hopeless. In 1985, the first latent fingerprint search on San Francisco's computer turned up the killer of Miriam Slamovich, a World War II concentration camp survivor who had been shot in the throat by a home intruder seven years earlier. The killer was arrested the same day.

Now electronic fingerprinting is catching on in the office. "The biggest applications are the 'log in' process," says William



Biometric IDs take many forms. Ancient Israeli potters used thumbprints as signatures. Nineteenth-century police in Paris measured suspects' fingers, ears, and head sizes to target repeat offenders. Passport photos verify the identity of travelers. Now DNA has become a powerful way to match criminals with their crimes.

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BRIEF SUMMARY.

CLINICAL PHARMACOLOGY Pharmacokinetics and Metabolism: Omeprazole – In pharmacokinetic studies of single 20 mg omeprazole doses, an increase in AUC of approximately four-fold was noted in Asian subjects compared to Caucasians. Dose adjustment, particularly where maintenance of healing of erosive esophagitis is indicated, for the hepatically impaired and Asian subjects should be considered.

INDICATIONS AND USAGE Duodenal Ulcer: PRILOSEC is indicated for short-term treatment of active duodenal ulcer. Most patients heal within 4 weeks. Some patients may require an additional 4 weeks of therapy. PRILOSEC, in combination with clarithromycin and amoxicillin, is indicated for treatment of patients with *H. pylori* infection and duodenal ulcer disease (active or up to 1-year history) to eradicate *H. pylori*. PRILOSEC, in combination with clarithromycin, is also indicated for treatment of patients with *H. pylori* infection and duodenal ulcer disease to eradicate *H. pylori*. Eradication of *H. pylori* has been shown to reduce the risk of duodenal ulcer recurrence. Among patients who fail therapy, PRILOSEC with clarithromycin is more likely to be associated with the development of clarithromycin resistance as compared with triple therapy. In patients who fail therapy, susceptibility testing should be done. If resistance to clarithromycin is demonstrated or susceptibility testing is not possible, alternative antimicrobial therapy should be instituted. (See the clarithromycin package insert, MICROBIOLOGY section.) **Gastric Ulcer:** PRILOSEC is indicated for short-term treatment (4-8 weeks) of active benign gastric ulcer. **Treatment of Gastroesophageal Reflux Disease (GERD): Symptomatic GERD** – PRILOSEC is indicated for the treatment of heartburn and other symptoms associated with GERD. **Erosive Esophagitis** – PRILOSEC is indicated for the short-term treatment (4-8 weeks) of erosive esophagitis which has been diagnosed by endoscopy. The efficacy of PRILOSEC used for longer than 8 weeks in these patients has not been established. In the rare instance of a patient not responding to 8 weeks of treatment, it may be helpful to give up to an additional 4 weeks of treatment. If there is recurrence of erosive esophagitis or GERD symptoms (e.g., heartburn), additional 4-8 week courses of omeprazole may be considered. **Maintenance of Healing of Erosive Esophagitis:** PRILOSEC is indicated to maintain healing of erosive esophagitis. Controlled studies do not extend beyond 12 months. **Pathological Hypersecretory Conditions:** PRILOSEC is indicated for the long-term treatment of pathological hypersecretory conditions (e.g., Zollinger-Ellison syndrome, multiple endocrine adenomas and systemic mastocytosis).

CONTRAINDICATIONS Omeprazole: PRILOSEC Delayed-Release Capsules are contraindicated in patients with known hypersensitivity to any component of the formulation. **Clarithromycin:** Clarithromycin is contraindicated in patients with a known hypersensitivity to any macrolide antibiotic. Concomitant administration of clarithromycin with cisapride, pimozide, or terfenadine is contraindicated. There have been post-marketing reports of drug interactions when clarithromycin and/or erythromycin are co-administered with cisapride, pimozide, or terfenadine resulting in cardiac arrhythmias (QT prolongation, ventricular tachycardia, ventricular fibrillation, and torsades de pointes) most likely due to inhibition of hepatic metabolism of these drugs by erythromycin and clarithromycin. Fatalities have been reported. (Please refer to full prescribing information for clarithromycin before prescribing.) **Amoxicillin:** Amoxicillin is contraindicated in patients with a history of allergic reaction to any of the penicillins. (Please refer to full prescribing information for amoxicillin before prescribing.)

WARNINGS: **Clarithromycin:** CLARITHROMYCIN SHOULD NOT BE USED IN PREGNANT WOMEN EXCEPT IN CLINICAL CIRCUMSTANCES WHERE NO ALTERNATIVE THERAPY IS APPROPRIATE. IF PREGNANCY OCCURS WHILE TAKING CLARITHROMYCIN, THE PATIENT SHOULD BE APPRISED OF THE POTENTIAL HAZARD TO THE FETUS. (See WARNINGS in prescribing information for clarithromycin.) **Amoxicillin:** SERIOUS AND OCCASIONALLY FATAL HYPERSENSITIVITY (anaphylactic) REACTIONS HAVE BEEN REPORTED IN PATIENTS ON PENICILLIN THERAPY. THESE REACTIONS ARE MORE LIKELY TO OCCUR IN INDIVIDUALS WITH A HISTORY OF PENICILLIN HYPERSENSITIVITY AND/OR A HISTORY OF SENSITIVITY TO MULTIPLE ALLERGENS. BEFORE INITIATING THERAPY WITH AMOXICILLIN, CAREFUL INQUIRY SHOULD BE MADE CONCERNING PREVIOUS HYPERSENSITIVITY REACTIONS TO PENICILLINS, CEPHALOSPORINS OR OTHER ALLERGENS. IF AN ALLERGIC REACTION OCCURS, AMOXICILLIN SHOULD BE DISCONTINUED AND APPROPRIATE THERAPY INSTITUTED. SERIOUS ANAPHYLACTIC REACTIONS REQUIRE IMMEDIATE EMERGENCY TREATMENT WITH EPINEPHRINE, OXYGEN, INTRAVENOUS STEROIDS AND AIRWAY MANAGEMENT, INCLUDING INTUBATION, SHOULD ALSO BE ADMINISTERED AS INDICATED. (See WARNINGS in prescribing information for amoxicillin.) **Antimicrobials:** Pseudomembranous colitis has been reported with nearly all antibacterial agents and may range in severity from mild to life-threatening. Therefore, it is important to consider this diagnosis in patients who present with diarrhea subsequent to the administration of antibacterial agents. (See WARNINGS in prescribing information for clarithromycin and amoxicillin.)

PRECAUTIONS General: Symptomatic response to therapy with omeprazole does not preclude the presence of gastric malignancy. Atrophic gastritis has been noted occasionally in gastric corpus biopsies from patients treated long-term with omeprazole. **Information for Patients:** PRILOSEC Delayed-Release Capsules should be taken before eating. Patients should be cautioned that the PRILOSEC Delayed-Release Capsule should not be opened, chewed or crushed, and should be swallowed whole. **Drug Interactions:** Other – Omeprazole can prolong the elimination of diazepam, warfarin and phenytoin, drugs that are metabolized by oxidation in the liver. Although in normal subjects no interaction with theophylline or propranolol was found, there have been clinical reports of interaction with other drugs metabolized via the cytochrome P-450 system (e.g., cyclosporine, disulfiram, benzodiazepines). Patients should be monitored to determine if it is necessary to adjust the dosage of these drugs when taken concomitantly with PRILOSEC. Because of its profound and long lasting inhibition of gastric acid secretion, it is theoretically possible that omeprazole may interfere with absorption of drugs where gastric pH is an important determinant of their bioavailability (e.g., ketoconazole, ampicillin esters, and iron salts). In the clinical trials, antacids were used concomitantly with the administration of PRILOSEC. **Combination Therapy with Clarithromycin** – Co-administration of omeprazole and clarithromycin have resulted in increases in plasma levels of omeprazole, clarithromycin, and 14-hydroxy-clarithromycin. (See CLINICAL PHARMACOLOGY, Pharmacokinetics.) **Combination Therapy with Amoxicillin:** In full Prescribing Information. Concomitant administration of clarithromycin with cisapride, pimozide, or terfenadine is contraindicated. There have been reports of an interaction between erythromycin and astemizole resulting in QT prolongation and torsades de pointes. Concomitant administration of erythromycin and astemizole is contraindicated. Because clarithromycin is also metabolized by cytochrome P450, concomitant administration of clarithromycin with astemizole is not recommended. (See also CONTRAINDICATIONS, Nausea, above. Please refer to full prescribing information for clarithromycin.) **Carcinogenesis, Mutagenesis, Impairment of Fertility:** In two 24-month carcinogenicity studies in rats, omeprazole at daily doses of 1.7, 3.4, 13.8, 44.0 and 140.8 mg/kg/day (approximately 4 to 352 times the human dose, based on a patient weight of 50 kg and a human dose of 20 mg) produced gastric ECL cell carcinoids in a dose-related manner in both male and female rats; the incidence of this effect was markedly higher in female rats, which had higher blood levels of omeprazole. Gastric carcinoids seldom occur in the untreated rat. In addition, ECL cell hyperplasia was present in all treated groups of both sexes. In one of these studies, female rats were treated with 13.8 mg/kg/day omeprazole (approximately 35 times the human dose) for 1 year, then followed for an additional year without the drug. No carcinoids were seen in these rats. An increased incidence of treatment-related ECL cell hyperplasia was observed at the end of 1 year (94% treated vs 10% controls). By the second year the difference between treated and control rats was much smaller (46% vs 26%) but still showed more hyperplasia in the treated group. An unusual primary malignant tumor in the stomach was seen in one rat (2%). No similar tumor was seen in male or female rats treated for 2 years. For this strain of rat no similar tumor has been noted historically, but a finding involving only one tumor is difficult to interpret. A 78-week mouse carcinogenicity study of omeprazole did not show increased tumor occurrence, but the study was not conclusive. Omeprazole was not mutagenic in an *in vitro* Ames Salmonella typhimurium assay, an *in vitro* mouse lymphoma cell assay and an *in vivo* rat liver DNA damage assay. A mouse micronucleus test at 625 and 6250 times the human dose gave a borderline result, as did an *in vivo* bone marrow chromosome aberration test. A second mouse micronucleus study at 2000 times the human dose, but with different (suboptimal) sampling times, was negative. **Pregnancy:** Omeprazole: **Pregnancy Category C** – In rabbits, omeprazole in a dose range of 6.9 to 69.1 mg/kg/day (approximately 17 to 172 times the human dose) produced dose-related increases in embryo-letality, fetal resorptions and pregnancy disruptions. In rats, dose-related embryo/fetal toxicity and postnatal developmental toxicity were observed in offspring resulting from parents treated with omeprazole 13.8 to 138.0 mg/kg/day (approximately 35 to 345 times the human dose). There are no adequate or well-controlled studies in pregnant women. Sporadic reports have been received of congenital abnormalities occurring in infants born to women who have received omeprazole during pregnancy. Omeprazole should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus. **Clarithromycin:** **Pregnancy Category C** – See WARNING (above) and full prescribing information for clarithromycin before using in pregnant women. **Nursing Mothers:** It is not known whether omeprazole is excreted in human milk. In rats, omeprazole administration during late gestation and lactation at doses of 13.8 to 138 mg/kg/day (35 to 345 times the human dose) resulted in decreased weight gain in pups. Because many drugs are

excreted in human milk, because of the potential for serious adverse reactions in nursing infants from omeprazole, and because of the potential for tumorigenicity shown for omeprazole in rat carcinogenicity studies, a decision should be made whether to discontinue nursing or discontinue the drug, taking into account the importance of the drug to the mother. **Pediatric Use:** Safety and effectiveness in pediatric patients have not been established.

ADVERSE REACTIONS: In the U.S. clinical trial population of 465 patients (including duodenal ulcer, Zollinger-Ellison syndrome and resistant ulcer patients), the following adverse experiences were reported to occur in 1% or more of patients on therapy with PRILOSEC® (omeprazole). Numbers in parentheses indicate percentages of the adverse experiences considered by investigators as possibly, probably, or definitely related to the drug.

	Omeprazole (n=465)	Placebo (n=64)	Ranitidine (n=195)
Headache	6.9 (2.4)	6.3	7.7 (2.6)
Diarrhea	3.0 (1.9)	3.1 (1.6)	2.1 (0.5)
Abdominal Pain	2.4 (0.4)	3.1	2.1
Nausea	2.2 (0.9)	3.1	4.1 (0.5)
URI	1.9	1.6	2.6
Dizziness	1.5 (0.6)	0.0	2.6 (1.0)
Vomiting	1.5 (0.4)	4.7	1.5 (0.5)
Rash	1.5 (1.1)	0.0	0.0
Constipation	1.1 (0.9)	0.0	0.0
Cough	1.1	0.0	1.5
Asthenia	1.1 (0.2)	1.6 (1.6)	1.5 (1.0)
Back Pain	1.1	0.0	0.5

The following adverse reactions which occurred in 1% or more of omeprazole-treated patients have been reported in international double-blind, and open-label, clinical trials in which 2,631 patients and subjects received omeprazole.

Incidence of Adverse Experiences ≥ 1%, Causal Relationship Not Assessed

	Omeprazole (n=2631)	Placebo (n=120)
Body as a Whole, site unspecified		
Abdominal pain	5.2	3.3
Asthenia	1.3	0.8
Constipation	1.5	0.8
Diarrhea	3.7	2.5
Flatulence	2.7	5.8
Nausea	4.0	6.7
Vomiting	3.2	10.0
Acid regurgitation	1.9	3.3
Headache	2.9	2.5
Nervous System/Psychiatric		

Additional adverse experiences occurring in <1% of patients or subjects in domestic and/or international trials, or occurring since the drug was marketed, are shown below within each body system. In many instances, the relationship to PRILOSEC was unclear. **Body As a Whole:** Allergic reactions including, rarely, anaphylaxis (see also Skin below), fever, pain, fatigue, malaise, abdominal swelling. **Cardiovascular:** Chest pain or angina, tachycardia, bradycardia, palpitation, elevated blood pressure, peripheral edema. **Gastrointestinal:** Pancreatitis (some fatal), anorexia, irritable colon, flatulence, fecal discoloration, esophageal candidiasis, mucosal atrophy of the tongue, dry mouth. During treatment with omeprazole, gastric fundic gland polyps have been noted rarely. These polyps are benign and appear to be reversible when treatment is discontinued. Gastro-duodenal carcinoids have been reported in patients with ZE syndrome on long-term treatment with PRILOSEC. This finding is believed to be a manifestation of the underlying condition, which is known to be associated with such tumors. **Hepatic:** Mild and, rarely, marked elevations of liver function tests [ALT (SGPT), AST (SGOT), γ -glutamyl transpeptidase, alkaline phosphatase, and bilirubin (jaundice)]. In rare instances, overt liver disease has occurred, including hepatocellular cholestasis, or mixed hepatitis, liver necrosis (some fatal), hepatic failure (some fatal), and hepatic encephalopathy. **Metabolic/Nutritional:** Hyponatremia, hypoglycemia, weight gain. **Musculoskeletal:** Muscle cramps, myalgia, muscle weakness, joint pain, leg pain. **Nervous System/Psychiatric:** Psychotic disturbances including depression, aggression, hallucinations, confusion, insomnia, nervousness, tremors, apathy, somnolence, anxiety, dream abnormalities; vertigo; paresthesia; hemifacial dysesthesia. **Respiratory:** Epistaxis, pharyngeal pain. **Skin:** Rash and, rarely, cases of severe generalized skin reactions including toxic epidermal necrolysis (TEN; some fatal), Stevens-Johnson syndrome, and erythema multiforme (some severe); purpura and/or petechiae (some with rechallenge); skin inflammation, urticaria, angioedema, pruritus, alopecia, dry skin, hyperhidrosis. **Special Senses:** Tinnitus, taste perversion. **Urogenital:** Interstitial nephritis (some with positive rechallenge), urinary tract infection, microscopic pyuria, urinary frequency, elevated serum creatinine, proteinuria, hematuria, glycosuria, testicular pain, gynecomastia. **Hematologic:** Rare instances of pancytopenia, agranulocytosis (some fatal), thrombocytopenia, neutropenia, anemia, leucocytosis, and hemolytic anemia have been reported. **Combination Therapy for *H. pylori* Eradication:** dual therapy with PRILOSEC and clarithromycin, or triple therapy with PRILOSEC, clarithromycin, and amoxicillin. Adverse experiences that have occurred have been limited to those that have been previously reported with omeprazole, clarithromycin, or amoxicillin. **Triple Therapy (PRILOSEC/clarithromycin/amoxicillin):** The most frequent adverse experiences observed in clinical trials using combination therapy with PRILOSEC, clarithromycin, and amoxicillin (n = 274) were diarrhea (14%), taste perversion (10%), and headache (7%). None of these occurred at a higher frequency than that reported by patients taking the antimicrobial drugs alone. **Dual Therapy (PRILOSEC/clarithromycin):** Adverse experiences observed in controlled clinical trials using combination therapy with PRILOSEC and clarithromycin (n = 346) which differed from those previously described for omeprazole alone were: Taste perversion (15%), tongue discoloration (2%), rhinitis (2%), pharyngitis (1%) and flu syndrome (1%). For more information on clarithromycin or amoxicillin, refer to the respective package inserts, ADVERSE REACTIONS sections.

OVERDOSSAGE: Rare reports have been received of overdosage with omeprazole. Doses ranged from 320 mg to 900 mg (16-45 times the usual recommended clinical dose). Manifestations were variable, but included confusion, drowsiness, blurred vision, tachycardia, nausea, diaphoresis, flushing, headache, and dry mouth. Symptoms were transient, and no serious clinical outcome has been reported. No specific antidote for omeprazole overdosage is known. Omeprazole is extensively protein bound and is, therefore, not readily dialyzable. In the event of overdosage, treatment should be symptomatic and supportive.

DOSSAGE AND ADMINISTRATION Short-Term Treatment of Active Duodenal Ulcer: The recommended adult oral dose of PRILOSEC is 20 mg once daily. Most patients heal within 4 weeks. Some patients may require an additional 4 weeks of therapy. (See INDICATIONS AND USAGE.) ***H. pylori* Eradication for the Reduction of the Risk of Duodenal Ulcer Recurrence Triple Therapy (PRILOSEC/clarithromycin/amoxicillin):** The recommended adult oral regimen is PRILOSEC 20 mg plus clarithromycin 500 mg plus amoxicillin 1000 mg each given twice daily for 10 days. In patients with an ulcer present at the time of initiation of therapy, an additional 14 days of PRILOSEC 20 mg once daily is recommended for ulcer healing and symptom relief. **Dual Therapy (PRILOSEC/clarithromycin):** The recommended adult oral regimen is PRILOSEC 40 mg once daily plus clarithromycin 500 mg t.i.d. for 14 days. In patients with an ulcer present at the time of initiation of therapy, an additional 14 days of PRILOSEC 20 mg once daily is recommended for ulcer healing and symptom relief. Please refer to clarithromycin full prescribing information for CONTRAINDICATIONS and WARNING, and for information regarding dosing in elderly and renally impaired patients. (PRECAUTIONS: General, PRECAUTIONS: Geriatric Use and PRECAUTIONS: Drug Interactions.) Please refer to amoxicillin full prescribing information for CONTRAINDICATIONS and WARNINGS. **Gastric Ulcer:** The recommended adult oral dose is 40 mg once a day for 4 to 8 weeks. (See INDICATIONS AND USAGE, Gastric Ulcer.) **Gastroesophageal Reflux Disease (GERD):** The recommended adult oral dose for the treatment of patients with symptomatic GERD and no esophageal lesions is 20 mg daily for up to 4 weeks. The recommended adult oral dose for the treatment of patients with erosive esophagitis and accompanying symptoms due to GERD is 20 mg daily for 4 to 8 weeks. (See INDICATIONS AND USAGE.) **Maintenance of Healing of Erosive Esophagitis:** The recommended adult oral dose is 20 mg daily. **Pathological Hypersecretory Conditions:** The dosage of PRILOSEC in patients with pathological hypersecretory conditions varies with the individual patient. The recommended adult oral starting dose is 60 mg once a day. Doses should be adjusted to individual patient needs and should continue for as long as clinically indicated. Doses up to 120 mg t.i.d. have been administered. Daily dosages of greater than 80 mg should be administered in divided doses. No dosage adjustment is necessary for patients with renal impairment, hepatic dysfunction or for the elderly.

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December 1998

PR131

→ H. Saito, president and CEO of I/O Software, a California firm that sells software for fingerprint and face recognition systems. Instead of having employees remember dozens of passwords for different computer systems, companies are using biometric systems to implement "single sign-on," Saito says. A worker just sits down at the computer, presses a thumb against a credit-card-sized scanner, and the system automatically unlocks the files and applications that person is authorized to use.

"Among the Fortune 1000 companies it is a no-brainer," says Saito. He also sees interest in biometrics spreading to small offices and home-computer users. "We can prevent an application launch—we won't let people launch Quicken, for example, without a fingerprint," he says. A family with a single home computer could use this technology to prevent teenage kids from accessing Mom and Dad's financial records. I/O's software can also control the Web browser, so that younger family members can access only specific Web sites. Eventually, fingerprints might also be used to fi-

surement with the wrong template, and false negatives, in which the computer failed to identify a real match. Today's systems are far more accurate, thanks to faster computers, but they still make mistakes.

Voiceprint IDs, a staple of science fiction since *Star Trek* in the 1960s, haven't found widespread use largely because of technical difficulties. "The inherent problem is that all microphones are not created equal," says Saito. "Ambient noise is another problem, especially if you are outside on a tarmac, inside a client's office, or in a classroom full of kids." Or, in my case, standing in the rain, trying to get the voiceprint lock to open between thunderclaps.

Striations in the eye's iris are a thousand times more distinctive than the whorls on a finger, so in principle iris prints should be even more reliable than fingerprints. In 1995, the first iris scanners were successfully deployed to provide security for prison doors and bank vaults, says Lou Sassano, vice president of worldwide sales for IriScan, a New Jersey company that holds patents on the technology. Bank United of Texas

people in the car. Then a pair of radios would transmit the image to the police station, where a computer would run a comparison against a face-recognition database and transmit an alert to the officer if the driver were wanted or dangerous. Another Viisage product, called Hunter, is designed to pick out known terrorists from airport surveillance cameras. More than 50 casinos already use a similar system of hidden video cameras and computers to identify known scam artists and cardsharps.

FINGERPRINTS MIGHT BE
USED TO FINALIZE
BUSINESS TRANSACTIONS
OVER THE INTERNET.
PRESIDENT CLINTON
RECENTLY APPROVED A
BILL THAT WOULD MAKE
SUCH ELECTRONIC
SIGNATURES AS LEGALLY
BINDING AS PEN AND INK



THEY'RE NOT JUST WINDOWS TO THE SOUL—YOUR EYES CONTAIN DISTINCTIVE PATTERNS THAT BETRAY YOUR IDENTITY. IRISCAN'S PORTABLE IRIS READER LINKS TO A PC TO CONTROL WHO CAN LOG ON.

nalize business transactions—tax payments or home refinancing, for instance—conducted over the Internet. President Clinton recently approved a bill that would make such electronic signatures as legally binding as traditional ones in pen and ink.

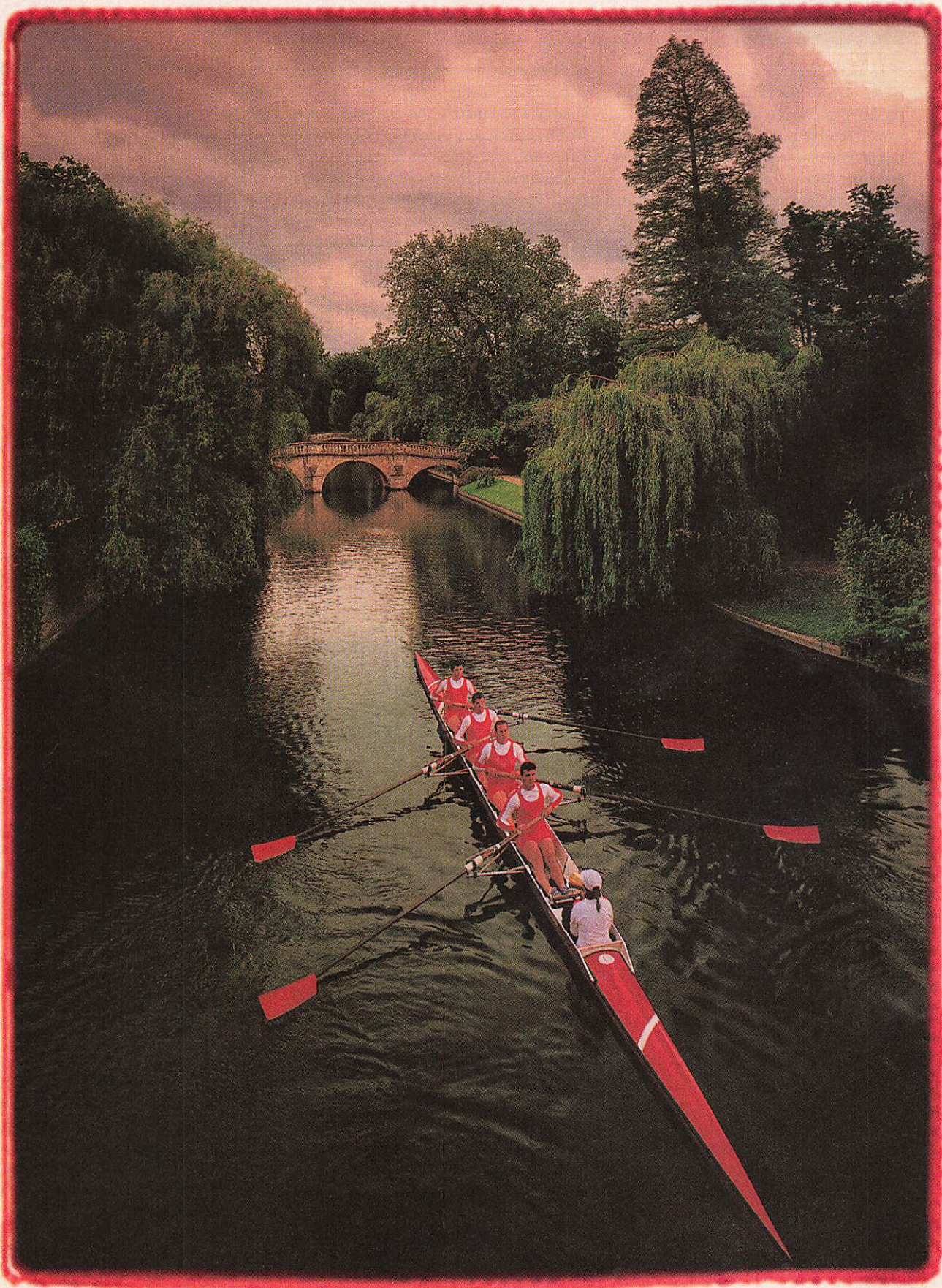
Sounds promising, but commercial biometrics has a history of false starts. That's because the systems don't actually identify a person; they merely compare a measurement of the human body with a stored template. If the measurement and the template are similar enough, the comparing software declares the two a match. Early systems sold in the 1980s didn't do very well on these comparisons. They were subject to high numbers of false positives, in which the system erroneously matched a person's mea-

surement with the wrong template, and false negatives, in which the computer failed to identify a real match. Today's systems are far more accurate, thanks to faster computers, but they still make mistakes.

Part of the appeal of iris prints is that they require no special action—they can be read without a person's knowledge. Facial recognition is prone to error but is even more stealthy. Viisage Technology, a Massachusetts firm, has developed a system that would allow police to scan a driver after they stop a vehicle. Their approach, based on technology developed at the Massachusetts Institute of Technology Media Lab in the early 1990s, would use a hidden camera on the officer's collar to photograph

This ability to surreptitiously identify people rings alarm bells for many civil libertarians. Merchants could build a mailing list of every pedestrian who looked with interest in a store window—or deny entrance to suspected shoplifters. Police could use outdoor video cameras to build a list and then question every person who happened to walk in that area after a crime had been committed. A prototype of such a system is being tested in Newham, England.

There are no laws in the United States to regulate the collection or use of biometric information. "Biometrics is one of the most urgent privacy issues," says Marc Rotenberg, director of the Electronic Privacy Information Center. Biometric identifiers could replace social-security numbers and become a kind of "informational flypaper," he says, so that everything about you—your product preferences, credit history, youthful indiscretions—sticks with you for life. Someday you might feel a strange nostalgia for old-fashioned signatures and ATM cards, not to mention locks and keys. ☒



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TECHNOLOGY

Each morning, on the willow-banked rivers of England, a quiet ritual takes place. For more than a hundred years, teams of college rowers have broken the stillness of the river waters with the synchronized pull of their oars. To the traveler, it's a quintessentially English scene,

Toyota manufacturing plant



Derbyshire, UK

dignified and serene, as if torn from the pages of a novel by Waugh or Forster.

Indeed. However, down on the water, the rowers themselves may be taking a very different view of the action. Today's teams use computers to maximize their stroke and space-age materials to improve the performance of their boats. Team pride is everything. And competition is fierce.

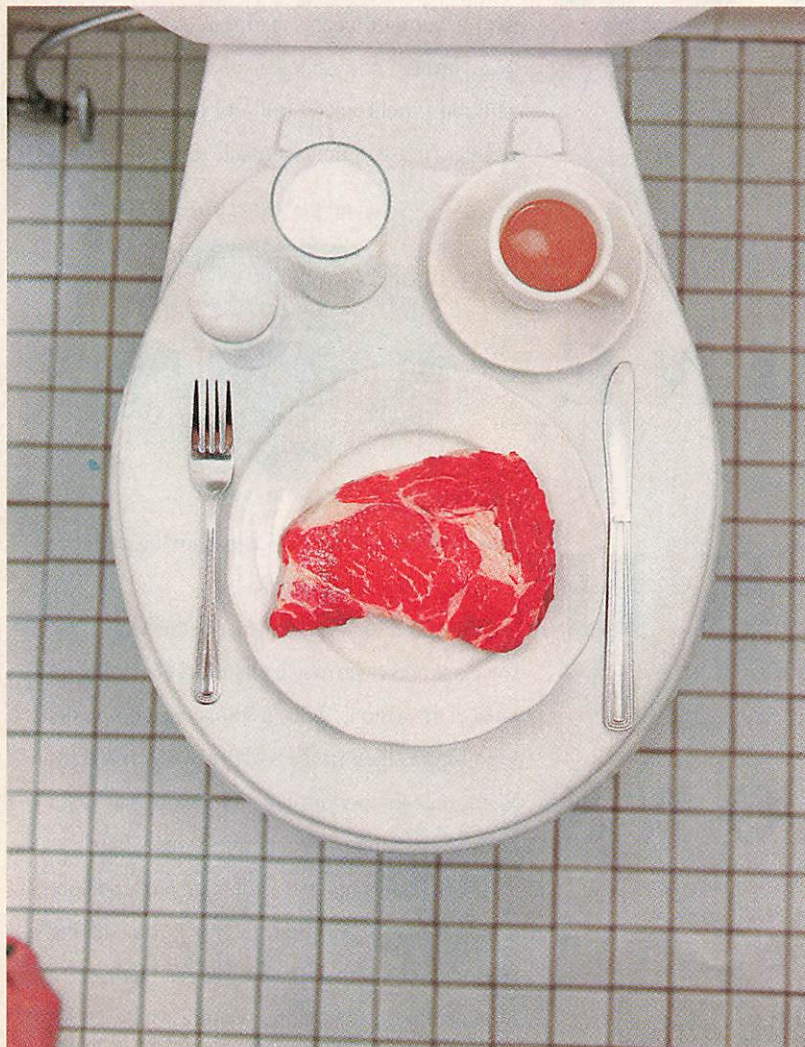
Perhaps this unique combination of tradition, teamwork and forward-thinking is one of the reasons behind the success of our Derbyshire manufacturing operations. Where, since 1992, local team members have produced more than one million Toyota vehicles for markets within the UK and Europe.

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It takes teamwork to move forward. Just ask any rower.

TOYOTA People Drive Us



Gut Instincts

Why do pregnant women get nauseated just when their bodies most need food?

"IF YOU EVER COOK MEAT IN THIS HOUSE AGAIN, I'M LEAVING." THOSE WERE not the words of a vegetarian but of a woman eight weeks pregnant with a whiff of steak up her nose—my nose. Usually, I was happy to chow down on a hunk of meat, and I hadn't lost my appetite for most other foods. But suddenly, the smell of broiling cow had me heading for the toilet. Of all the things I could have hated, why meats?

New mothers, guided by their doctors, have attributed such aversions to the hormonal storm brewing inside them, or to the roller-coaster emotions that attend pregnancy. But in the late 1980s, biologists such as Margie Profet, of the University of California

at Berkeley, offered a new explanation: Morning sickness, she said, could be an evolutionary adaptation, one that protects a vulnerable fetus from natural toxins. By avoiding certain foods during pregnancy, women may improve their chances of having healthy children—and so pass on the same aversion to future generations.

This summer, that idea became science when Cornell University graduate student Samuel Flaxman and his adviser, neurobiologist Paul Sherman, published the results of a cross-cultural study in *The Quarterly Review of Biology*. Their data confirmed the outlines of the evolutionary theory, but the details came as a surprise. Whereas Profet and others suggested that primarily vegetables and spices trigger morning sickness, the new study fingered meat, fish, poultry, and eggs. Many women avoid these foods early in pregnancy when fetal organs are forming, Flaxman and Sherman found. And the evolutionary reason seems clear: Meat was once the food most likely to carry parasites and pathogens that could harm a fetus, as well as put a mother at risk.

"Morning sickness is a misnomer," Paul Sherman explained recently, over lunch at a Vietnamese restaurant on the edge of the Cornell campus. "It's not always in the morning but happens all day long for most women. And it's not a real sickness, but really something positive." Getting sick makes sense early in pregnancy, Sherman says. When the body is invaded by something—be it a virus or a ball of foreign cells called an embryo—nausea often results. Estrogen, progesterin, and other hormones clearly mediate this response, and studies show that women who have some form of sickness are less likely to miscarry. But contrary to conventional wisdom, high hormone levels don't necessarily translate into severe morning sickness. In fact, women with morning sickness tend to have no more estrogen and progesterin than women without it.

Flaxman and Sherman looked at the results of 56 morning sickness studies covering 79,000 pregnancies in 16 countries. Sixty-six percent of pregnant women, they found, reported some sort of illness in weeks six through 14 of their pregnancy. More interesting, about 65 percent of the women had an aversion to at least one food—far too many for the aversions to be merely whimsical. Among those women, 16 percent avoided caffeinated drinks, 8 percent avoided such strong-tasting vegetables →



In some traditional African cultures, women eat a type of clay with antidiarrheal properties during the early stages of their pregnancy. Neurobiologist Paul Sherman speculates that the clay might bind to toxic chemicals and bacteria in the gut, thus preventing fetal damage. "It works just like Kaopectate," he says.

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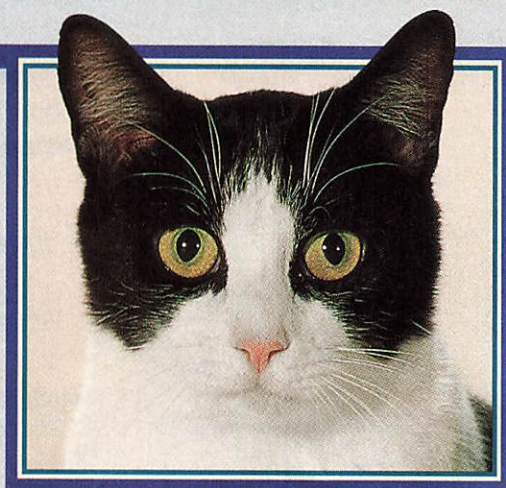
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→ as broccoli and cabbage, and 4 percent avoided spicy ethnic food—all of which contain natural toxins, called secondary compounds, which protect plants from pests and pathogens. A full 28 percent, however, couldn't stomach animal products, especially meat, poultry, eggs, or fish.

The Cornell team found further proof of this pattern by comparing anthropological reports from 27 societies where the early symptoms of pregnancy were discussed. In seven of those societies, morning sickness

**PREGNANT WOMEN IN
MEAT-EATING SOCIETIES
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CARRY COULD BE
DANGEROUS—HENCE
MORNING SICKNESS**

was all but unknown. In 20 others, it was common. Societies in the first group rarely ate animal products, relying instead on corn, rice, tubers, and other plants. Most in the second group drank milk or ate fish or meat.

Pregnant women in meat-eating societies seem to be caught in a double bind. Their fetuses could use the protein in meat, but the pathogens it might carry are too dangerous to ingest—hence morning sickness. In a previous study, another Cornell graduate student, Jennifer Billing, worked with Sherman to show that spices such as chili pepper, allspice, and oregano kill parasites and pathogens in food. "When you go to the local grocery store and look at the spice rack, it's an apothecary," Sherman says. "We're using those compounds to protect ourselves." Especially in hot climates, where meat spoils quickly, people traditionally use spices to disinfect their food. Unfortunately, pregnant mothers don't have that option: Spices contain natural toxins too. If spices are out, then pregnant women are better off avoiding foods that spoil altogether.

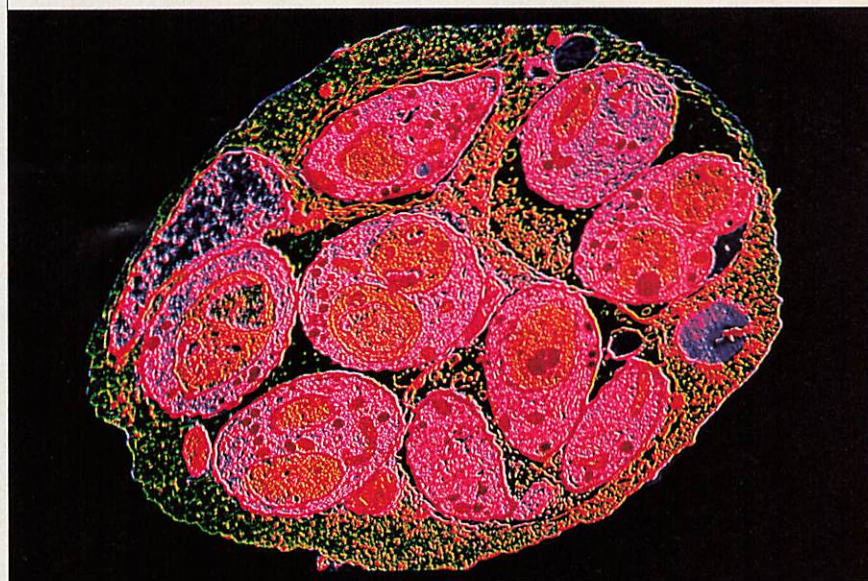
To most women, morning sickness seems to begin and end arbitrarily, yet its timing makes sense: A fetus's major organs develop between six and 14 weeks after conception. That's also when a mother's immune response temporarily weakens, giving the embryo time to burrow into the uterine wall. As a result, pregnant women are especially susceptible to bacteria, viruses, and tumor cells during those weeks. For example, spoiled food commonly contains toxoplasma, a protozoan parasite. Toxoplasma is usually harmless, but early in pregnancy it can cause maternal infection and possible miscarriage. Once the fetus is less vulnerable—after the first trimester, say—the nutritional value of meat outweighs the risk, and the aversion usually subsides.

All of which underscores the hazards of eating in general. "Everything we do in food preparation—boiling, drying, spicing, cooking—is aimed at avoiding our competitors, that is, parasites and pathogens," Sherman says. "These are things that people put in their mouths, and it's not trivial or unim-

against harmful parasites and pathogens might explain it," Sherman says. "One person tries a spice, and it also protects against gastrointestinal distress. That recipe is quickly passed on to others." Pregnant women are merely the pickiest cooks: Their bodies are designed to protect the bundle of genes growing inside them, even if it means having to puke their guts out.

Not long ago, paleontologists in Ethiopia found some 2½-million-year-old animal bones near the village of Bouri, in the Middle Awash region. They were the remains, it seems, of an australopithecine meal of three-toed-horse steak and antelope tongue. A million years later, our ancestors were hunting on a regular basis, but they were still a long way from inventing refrigerators to keep that meat in Grade-A condition. My guess is that pregnant hominids took one look at the day's kill and ran screaming from the bloody carcasses, just as I ran from my kitchen trying to escape the sight and smell of meat on the stove.

My recent meal with Sherman followed



Toxoplasma parasites (pink spheres), shown here infecting a cell, can be transmitted through undercooked meat. The infection can cause miscarriages in pregnant women. Morning sickness may be a defense.

portant." Across the generations, he suggests, the kitchen has been a battlefield marked by constantly shifting weapons and strategies. One strain of bacteria moves in only to be beaten back by a powerful spice or boiling water; then the strain mutates and spreads again, until another kind of spice can control it. "There is an evolution in cooking and recipes, and this arms race

a different path. With neither of us currently pregnant, we were free to dig into a very spicy pork dish and then linger over shrimp and noodles topped by a blistering red pepper paste. By the end of lunch, our eyes were watering and our noses were running, but we were smiling: If either of us happened to be carrying a lot of parasites in our stomachs, they were surely dead by then. ☒



**You still say cheese.
That much is the same.**



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North Dakota Diary

A stint on a family farm brings the shifting lives of the American middle class into focus

ON A SUNNY MORNING IN JUNE, AN OLD PICKUP JOUNCES AMONG THE ravines and hillocks of a North Dakota pasture. Already the heat portends one of the summer's first scorching days. Two men in the truck scan the barbed-wire fence line for slack sections and breaks. Sometimes the tall one gets out to walk beside the lumbering vehicle, hammering a staple into a wooden post to tighten a section here and there. Where the wire is especially loose, the men work together with a fence stretcher and splicing pliers. At the south end of the pasture they drive a new metal post into the ground.

The conversation is more lively than the work. When he's not showing the tall one how to mend a fence, the farmer with the cowboy hat talks about his daughter's wedding, his father's cultivation philosophy, his cousin's grazing practices, his neighbor's crops. The tall one plies the cowboy hat with questions until, around midmorning, he pulls a pen and a notepad out of his fanny

pack and jots a few things down. He's not taking notes on fence fixing. He's taking notes on the farmer.

Cal Hoff and Tom Fricke may be the most unlikely pair of field hands ever to work a fence line together. For the past two years,

Hoff and his farming family have been the subjects of an in-depth study by Fricke, one of the lead anthropologists in a nationwide program to study the changing work habits and family lives of ordinary, middle-class Americans. Fricke's home base is the University of Michigan in Ann Arbor, but he has lived and worked with the Hoff family for months at a time, braving irate Herefords, errant hailstorms, barbed humor, and barbed wire. His cowpoke status gives him a close-up view of farming communities in the American heartland. In return, the Hoff family get a chance to spread the word about the imperiled lifestyle they cherish—as well as another pair of hands to help out around the farm.

"Anthropologists call it participant observation," says Fricke. "Driving tractors →



The rural farming community of Richardton (population 626) in the heart of North Dakota has fewer residents today than it did in 1910, whereas the precincts of boomtowns like Denver and Las Vegas have more than doubled their populations over the past 10 years. Even the most robust Midwestern communities aren't growing that fast.

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In the spring, 24 regional teams will be chosen as semi-finalists and awarded prizes. These teams will then create functional Web sites to showcase their future technology ideas. Of the 24 teams, 8 finalist teams will be selected. Winners, their coaches and mentors will attend a gala awards ceremony in Washington, D.C., where each student member of the four first-place and four second-place teams will be awarded \$10,000 and \$5,000 U.S. Savings Bonds,* respectively. Honorable mentions will also be recognized for their creative vision.

FOR MORE INFORMATION ABOUT THE TOSHIBA/NSTA EXPLORAVISION AWARDS, AND TO VIEW LAST YEAR'S WINNERS' WEB SITES, CONNECT TO WWW.TOSHIBA.COM/TAI/EXPLORAVISION, CALL 1-800-EXPLORE-9 OR (703) 243-7100, OR WRITE TOSHIBA/NSTA EXPLORAVISION AWARDS, 1840 WILSON BOULEVARD, ARLINGTON, VA 22201.

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* Or Canadian Savings Bonds of comparable issue price.
Photography by: Chris Carroll

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The ideas represented here are a sampling of past ExploraVision winning entries.

→ and breaking things is mostly what I'm doing. I've shoveled cow manure out of pens in a barn. I'm a Ph.D. well traveled." Between chores Fricke documents family interactions, local history, civic functions, and moral perceptions among the 626 inhabitants of Richardton, a rail stop with a grain elevator 80 miles west of Bismarck. Fricke was drawn to North Dakota in part because he hails from the state. He ended up living with the Hoffs because, well, they let him.

"He was saying he didn't have a phone

LIKE MANY RURAL
COMMUNITIES,
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ITSELF. BUT NOW ITS
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THAT CAL HOFF TRACKS
WITH SOFTWARE AND A
SATELLITE FEED

at the hotel," says Cal's wife, Julie, recalling her first conversation with Fricke. "And I thought, well, we have phones."

The Hoffs also extended their hospitality because they are concerned with some of the same issues Fricke has come to study. Like many rural communities on the Great Plains, Richardton once sought to isolate itself from outside influences. But its farms must now participate in a global marketplace that Cal Hoff tracks hourly with sophisticated software and a satellite feed to his den. The Hoffs have also become the first family in the county to try no-till seeding, a method of cultivation Cal picked up in Canada during the slow winter months. It demands far less soil preparation and has allowed him to more than double his arable acreage. Meanwhile, the town of Richardton is suffering a slow decline as its young people leave in increasing numbers to seek their fortunes elsewhere. The Hoffs' oldest child, Crista, left home last year to study interior design at a college in Minneapolis. These "outside influences" are as intriguing to

Fricke as they are worrisome to the Hoffs.

"Notions of family relationship are bound to change when you go from a face-to-face, everyday-contact kind of world to something more episodic," says Fricke. Episodic encounters between far-flung family members usually revolve around holidays or special life events—births, funerals, or weddings, like Crista's nuptials with a local boy last June. Those occasions, emotionally charged to begin with, only become more tense and freighted when kin aren't sharing their daily lives, says Fricke. "The general heightening of emotional intensity means that small things get overblown. It's harder to resolve misunderstandings when you're feeling rushed and your emotions haven't ripened."

Fricke thinks the changes in Richardton could illuminate more general transformations in the American experience of work and family. A diaspora of kin, for example, is a common feature of family life in middle-class America. Back in Ann Arbor, at the Center for the Ethnography of Everyday Life, Fricke's colleagues are rounding out the picture with studies of day care, family leave, and family-planning practices in other milieus of Middle America. One professor is watching prime-time TV for clues to how media representations of family life influence the attitudes of real families; another is exploring the culture clash between innovators and managers at a dot-com startup. The idea is not just to quantify what middle-class Americans are doing but to discern why they're doing it and how their decisions create new ideals for work and family, as well as new tensions from failed, if outdated, expectations.

"I felt that anthropology would be ideal for looking at what's happening with mainstream American culture," says Kathleen Christensen, program director at the Alfred P. Sloan Foundation in New York, which funds five centers for the study of families, including the Michigan group. The program challenges anthropologists like Fricke to apply their tools and principles in a novel setting: everyday lives of middle-class families with two working parents. "That was not really a major direction of the field. Anthropology has typically looked at preindustrial cultures and at the exotic and the marginal in industrial cultures," says Christensen.

From his notepad scratchings on the Hoffs' everyday life, Fricke types up formal field notes and chatty letters for the folks

in Michigan. He also tapes interviews with the townsfolk to sound out their views on particular topics. Eventually these observations will suggest patterns that describe the local culture as well as the larger context in which it's embedded.

One of the themes to emerge from Fricke's study so far is the importance of geography in creating a sense of unity and continuity for families. "This is Hoff country," he says, surveying the county from an upland corner of a pasture. He points in every direction: "Hoff, Hoff, Hoff, Hoff, Hoff, Hoff," cousins and brothers, aunts and uncles, children and parents joined by real estate as well as by blood. "It's like the land itself maps out his family lines."

Fricke says the global, postindustrial economy uproots workers and demands that they stay mobile. But for many people, a sense of family, work, and place remain inseparable. He cites the case of the wealthiest family in Richardton, whose heirs moved away and sold off all the houses, barns, and land. They kept one unoccupied 14-acre parcel for family reunions, which helped maintain their ties to the past and one another.

Even for nuclear families, land and physical proximity seem to be critical for maintaining a sense of belonging and unity. Fricke's student, Brian Hoey, works in Traverse City, Michigan, where many newcomers have moved after abandoning lucrative jobs in big cities. "People are challenging the 'living to work' model," says Hoey. "They feel their lives are less fragmented here because it's all sort of closer together geographically: Their children's schools, their place of work, their homes, and their recreational opportunities are all right here."

Fricke hopes to shift his focus to the Richardton emigrants to see how they restructure their lives in the wide, rootless world. He suspects that their notions about work as well as family may get a shake-up when they move from the multifaceted, task-oriented culture of farming to the specialized, schedule-laden ethos of a service economy. But, he acknowledges, his own struggles with that transition promise to complicate his exploration.

"There's this old saying that a fish doesn't know that there's water," says Christensen. "It's the taken-for-granted aspects of our lives that someone really has to cultivate enough distance to be able to study and understand." ☒

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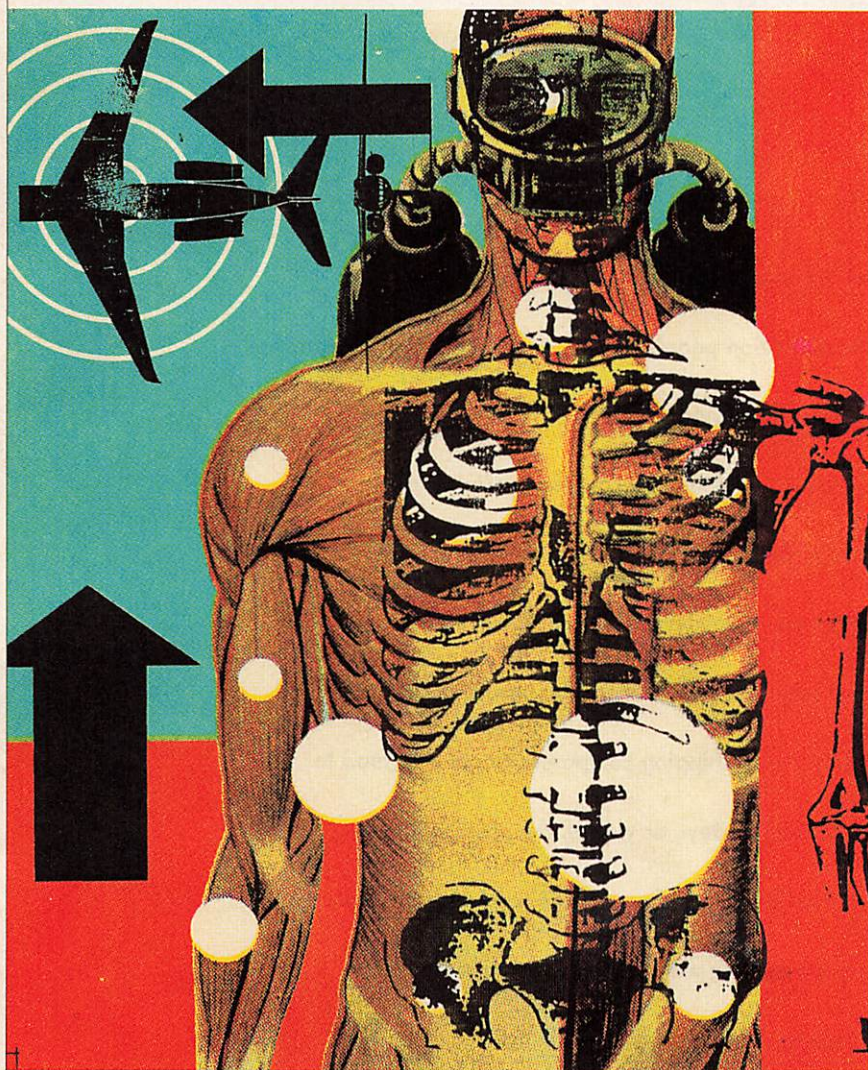
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Trouble on Flight 1368

A wonderful vacation puts newlyweds in a tailspin

"IF THERE ARE ANY DOCTORS ON THIS flight, could they please identify themselves by ringing the flight attendant call light?"

"I'm an ER doctor," I told the flight attendant.

"Well," she said, "she's back here."

In the last pair of seats sat a pleasant-looking young man and woman. She was sobbing loudly.

"Hey," I said. "I'm a doctor. What's going on?"

The young man looked up at me in bewilderment. "She's crying. I don't know why."

"You're traveling from Miami?"

"We're on our honeymoon," the man said, a little shyly. His wife nodded.

"Did you have a fight?" I asked.

"No," she said, "it was the most wonderful trip I ever had. I just feel like I want to die..."

The husband had an expression that read, "Would you fix this, please?"

"Has your wife ever seen a psychiatrist? Does she have any history of depression?"

"No," her husband said. "She's really, really healthy."

I looked at the woman. "Tell me what's going on now."

"I'm just so sad."

"Because you are going home?"

She shook her head. "I want to go home," she said, sobbing. "I miss my d-d-d-dogs."

"Have you ever been on anything for depression before, any drugs?"

"Never," she wailed, pounding the seat in front of her.

"When did you start feeling sad?"

Sad wasn't the right word. She was close to hysterical.

"When did this start?" I asked her husband.

"Just after we took off."

What produces psychiatric symptoms at cruising altitude in a plane? Hypoxia? A subtle stroke? I began to free-associate on "sadness." Maybe something nonorganic—not a physical illness. Maybe she was having an existential crisis, realizing, for the first time in her life, and at the altitude of 30,000 feet, how meaningless life can be.

I focused on Miami. "So you're coming from Miami?" I asked again.

"Bimini," he said. "The Bahamas. We flew in from there to Miami."

"How did you feel then?"

"When, on the plane? Not very good," she said. "I don't know... I just think this whole marriage thing was a big mistake."

"What did you do in Bimini?" I asked.

"We were scuba diving," the husband said.

"The whole week?"

"Yeah, we took a course at a resort."

"I'm a diver too," I told him. "How were you certified? PADI and NAUI?"

He looked at me, a little bewildered. "I don't know."

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Decompression sickness was first detected in the mid-19th century among workers building bridge foundations. Men who ascended too quickly after a long stint in the pressurized underground chamber suffered joint pain. The term *the bends* is derived from the victims' contorted posture. Slowing the ascent prevented the bends.

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→ When I dive, I usually travel with doctors, who are, of course, safety-conscious. Once, though, I had gone alone for a brief vacation to a dive resort in the Caribbean. It was the worst vacation of my life. That week the resort was filled with friends of the owner. Anyone was allowed to dive whether certified or not. No one used U.S. Navy Dive Tables, created to minimize the risk of the bends, or dive computers, or even much common sense. People would dive down 220 feet—an insane depth—to take pictures of a plastic chicken tied to a stake to prove they “dove with the chicken.”

Now I looked at the weeping wife. “What’s five times seven?” I asked.

“I don’t know.”

I LOOKED AT THE

WEeping WIFE. “WHAT’S

FIVE TIMES SEVEN?”

I ASKED. “I DON’T KNOW,”

SHE REPLIED. HER

HUSBAND LOOKED OVER,

ALARMED. “I FORGET,”

SHE ADDED. “I CAN’T

THINK.” THEN SHE TRIED.

“TWENTY-EIGHT?”

Her husband leaned over, even more alarmed.

“I forget,” she said. “I can’t think.” Then she tried for a moment. “Twenty-eight?”

I turned to the husband. “Did you keep a diving log?”

“Oh, yes,” he replied, pulling a notebook out of his carry-on bag. At least the resort had him do that much.

Diving logs record the depth and length of a dive. They help you figure out how close you are to the safety limits. The two major medical catastrophes that can occur with diving are air embolism and diver’s decompression sickness, or the bends. Air embolism occurs when a bubble of air is trapped in the bloodstream; although it can develop at any depth, it most frequently happens toward the surface. The bends (so called because the victims are sometimes

bent over by pain) can result from a diver staying in deep water too long.

Nitrogen is key. When a diver goes underwater, the ambient pressure increases dramatically. Ambient pressure doubles at 33 feet under the surface and, at 100 feet below, it’s four times atmospheric pressure. This pressure drives oxygen and, more important, nitrogen, from the air the diver breathes into the tissue. The extra nitrogen sits, inert, until the diver returns to the surface. If a diver rises slowly enough, the nitrogen gradually exits the tissue without problems. But if the diver rises too quickly, the sudden difference in ambient pressure forces nitrogen to pass out of the tissue into the gaseous state again, forming bubbles. The bubbles can form anywhere: muscles, where they can cause severe pain as they deform and disrupt muscle fibers; joints, where they can inflict even more pain; blood, where they can initiate blood clots; the heart, where they can precipitate a heart attack and other nasty things; and the brain, where they can cause anything from subtle memory loss to severe, irreversible stroke damage.

I looked at the weeping woman, then looked down at the logbook.

Divers work out their exposure to nitrogen under pressure using dive tables, a set of calculations developed in part by observing how long divers could stay underwater without getting bent. And that’s the problem: The Navy assumed that the user would always be a healthy young male Navy diver, not a middle-aged, overweight vacationer. And the tables are complicated, especially for multiple dives. That’s because there’s some residual nitrogen in tissues when you start a new dive. Diving computers can simplify the calculations, but you still need to understand what the calculations mean to use the dive tables correctly.

I opened up the dive log. There were 10 days of dives. The first dive was 25 feet, and the second and third dive bottomed out at 33 feet. After that, though, the dives went deeper and deeper, for longer and longer periods, until at the end, even without the tables handy, I could see that the couple had been very close to bends territory.

“Did you use the dive tables?” I asked the young man.

“Every day,” he said and added, “exactly.” Exactly. “Did you dive yesterday?”

“Of course,” he said. “It was our last day.”

The rule in diving is never to dive the day before you fly. The dive tables are created for sea level, and when you fly you reach an atmospheric pressure considerably lower than sea level. Therefore, more rapid nitrogen release can occur, and more nitrogen bubbles can form. Even if you don’t have the bends before you get on a plane, you can still experience symptoms when you reach cruising altitude.

One sign of the bends, I remembered, are subtle cognitive deficits. Could that involve a crying jag? Probably.

The treatment for the bends calls for a spell in a pressurized unit called a hyperbaric chamber, as well as supportive care with oxygen and fluids. In the chamber increased pressure drives the nitrogen back into the tissue, where it can dissipate under controlled circumstances and in the presence of lifesaving oxygen. If this young woman was actually suffering from the bends, she needed to spend time in a hyperbaric chamber—soon. We were stopping over in Louisville, Kentucky, which I was certain would have one.

I headed up to the cockpit.

“Does she need an ambulance?” the pilot asked.

“Anything with oxygen on it.”

When we landed in Louisville, the paramedics met us at the gate. When the young woman saw them she wailed even more. “I’m so embarrassed...”

I watched them leave. They had “pushed the tables,” as divers put it, but somehow only she had been affected. That would end her diving career. Because decompression illness can cause subtle but lasting changes in the circulatory system, doctors recommend that someone who has suffered the bends never dive again. ☒

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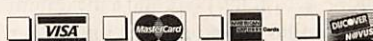
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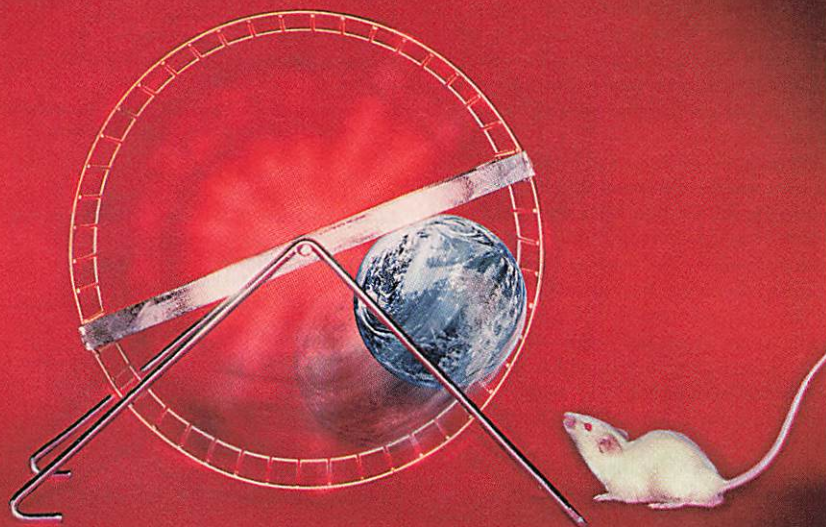
RICHARD WOLFSON, Ph.D., is a professor of physics at Middlebury College, where he has also held the George Adams Ellis Professorship of the Liberal Arts. A versatile physicist and science educator, Wolfson has published in such diverse fields as medical physics, experimental plasma physics, electronic circuit design, solar energy engineering, and theoretical astrophysics.

A legend among students for more than two decades at his own highly regarded campus, where his innovative and interesting courses are perennially filled, he is equally at home before a nontechnical audience. And his work outside the university arena, whether writing an article for *Scientific American* or creating a book-length explanation of *Nuclear Choices: A Citizen's Guide to Nuclear Technology*, has given Americans a new understanding of science and its impact on our lives in an age of extraordinary scientific discovery.

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WHILE SPRAWLED IN A LAWN CHAIR, MUNCHING A LABOR DAY HOT DOG UNDER the late-summer sun, you may feel perfectly at rest. It's an illusion, of course. Earth is spinning, orbiting, and swooping at hundreds of miles per second, carrying you on a complicated pathway through deep space. The motions range from the familiar progression around the sun, which touches off the start of autumn on September 22, to arcane movements that betray the hidden construction of the universe.

The primary step in this celestial dance is your daily circle on the spinning Earth, and your speed has everything to do with latitude—zero at the poles and a maximum of 1,040 miles per hour, or 0.3 miles per second, at the equator. If you're not afraid of the math, you can find your exact speed by multiplying the cosine of your latitude by 1,040. This works out to nearly 800 miles per hour in New York City or Indianapolis (latitude 40 degrees north) but just 450 mph in Fairbanks (65 degrees north).

The next complicating factor is Earth's yearly revolution around the sun, at an average speed of 18.5 miles per second. To get a feel for this movement, face the midday

sun and picture yourself orbiting to the right. When watching a sunrise, our planet's rotation carries you forward—that is, toward the sun—but the much faster orbital motion is hurling you upward, around the sun and toward a spot high in the south.

The sun itself takes a 250-million-year carousel ride around the nucleus of our galaxy, the Milky Way, dragging Earth along for the ride. Visualizing this swift motion,

some 140 miles per second, is particularly easy this month. Along with most of the stars of the night sky, we rush straight up at nightfall, toward the cross-shaped constellation Cygnus and its brightest star, Deneb, nearly overhead in early evening. The galaxy's densely packed nucleus hovers lowish in the south, marked by a brightening in the misty glow of the Milky Way.

The Milky Way, part of a small gathering of galaxies called the Local Group, is moving too. We're falling toward the center of the group at about 25 miles per second. And in 1969, scientists noticed a strange distortion in the ubiquitous cosmic microwave background, radiation thought to be left over from the Big Bang. That distortion implies that the whole galactic neighborhood is moving about 370 miles per second toward the constellation Hydra. This unexpected and still unexplained motion might result from the pull of vast superclusters or walls of galaxies—the biggest known structures in the universe.

Our celestial velocity could also reveal what holds the superclusters together. Cosmologists believe that more than 90 percent of the universe consists of dark matter—invisible subatomic particles that make themselves known only by their gravity. These particles, if they exist, do not generally associate with ordinary atoms, but they occasionally collide anyway, producing some secondary effects.

So as we circle the Milky Way's center, we should plow through swarms of dark matter. In June, our planet's orbit around the sun carries us in the same direction as the galactic rotation; in January, we move against the flow. We should therefore slam through more of the evanescent particles in summer than in winter. This past February, a Chinese-Italian research collaboration claimed to see just such an effect (see last month's Works in Progress column).

Interestingly, September brings not only the time of the equinox, when day and night are equal in duration. It also gives us the time of another equality, when Earth's motion about the sun neither adds to, nor subtracts from, our orbital velocity around the galaxy. Something to ponder as you savor the dwindling lazy days of summer. ☐



Sometimes there are strange numerical coincidences between different kinds of motion. The speed of light is 186,000 miles per second, while the diameter of Earth's orbit is 186 million miles. So a flash of light needs 1,000 seconds to cross our orbit. And Earth circles the sun at 18.5 miles per second, $\frac{1}{10,000}$ light speed.

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DANDRUFF SHOULD
NEVER GET IN THE WAY
OF BEING CLOSE.

SINCE THE DAWN OF SPACE EXPLORATION, we've tended to think of ourselves as making bold steps into the cosmos, when in fact we've hardly ventured very far at all. The U.S. and Soviet space programs have focused almost everything they've got on the nearest objects in our solar system—the moon, a mere 240,000 miles away; Venus, at 26 million miles; and Mars, 49 million miles away. The next planets in the echelon of the solar system—Jupiter and Saturn—have received

Out There

much less attention because they're magnitudes farther away—390 million miles and 794 million miles at their closest.

Only two spacecraft—*Voyager 1* and *Voyager 2*—have come close to the outer solar system planets of Uranus and Neptune. And neither probe was really intended to fly that far. Yet the more we begin to discover about the outer planets, as our article in this issue on Neptune reveals, the more they tell us about how Earth and the rest of the inner solar system were formed.

When *Voyager 2* first brought Uranus into view in 1986, no one got very excited. The planet hung in the sky as featureless as a balloon. But eight years later, when the Hubble Space Telescope began sending images of Uranus's satellites and rings, a few pictures showed enormous bright spots. "We thought, wait

a minute, this is odd—why does Uranus have clouds?" says Heidi Hammel, of the Space Science Institute.

A closer look has revealed a surprisingly active weather system. "Even on our ground-based images, we are seeing the northern hemisphere of Uranus chock-full of clouds," says Hammel. Why, then, did *Voyager 2* encounter a sleeping giant? Bad timing, says Hammel: When *Voyager 2* went by, it was winter. And because it takes Uranus 84 years to orbit the sun, the winters there last 21 years. Now, however, it's springtime on Uranus. The northern hemisphere is slowly revealing itself to modern astronomers for the first time and has created a stir.

"We never would have noticed this had we not had a few 'accidental' shots from the Hubble that forced us to take a closer look," says Hammel. "That's the way it is in astronomy: Serendipity leads you to new discoveries." Well, not just serendipity. Someone has to decide to look. As most of the articles in *Discover* reveal, curiosity leads to new discoveries too. Our article on Israeli ornithologist Reuven Yosef is a case in point. If Yosef and other bird-watchers in Israel had not chosen to look (below), no one would have learned that as many as half of Europe's birds depend on a single swamp in Eilat for the survival of their species. Ultimately, survival of our own species may depend on that same sort of curiosity about the heavens above us. ☒



TOM STODDART/IFP/MATRIX



VOYAGER 2'S FLYBY IN 1989 PROVIDED THE FIRST CLOSE-UP OF NEPTUNE—AND THE FIRST FULL VIEW OF ITS WISPY RINGS. PREVIOUS IMAGES HAD REVEALED ONLY INCOMPLETE ARCS. THE BRIGHT SPOTS IN THE BACKGROUND ARE STARS.

NEPTUNE RISING

ONCE A FUZZY NOBODY, NEPTUNE COMES OF AGE AS A KEY PLAYER IN THE ARRANGEMENT OF THE SOLAR SYSTEM. BESIDES, WHO CAN IGNORE A PLANET WHERE IT RAINS DIAMONDS?

FOR CENTURIES, THE PLANETARY GIANTS—Jupiter with its distinctive red spot and Saturn with its massive rings—have been the most glamorous of the planets, while the outer orbs—Uranus, Neptune, and Pluto—have been viewed, when they've been viewable at all, as dim, remote, drab, and mysterious stepsisters. Then 11 years ago *Voyager 2*, its mission to Jupiter and Saturn completed, was allowed to fly by and snap a few images of Neptune. What it eventually sent back to Earth changed everything. Neptune was literally seen in a new light, with images of a gorgeous blue orb with swirling white clouds that seemed, well, Earth-like. ¶ Three years later, the discovery of the Kuiper belt, a field of remote icy objects that includes Pluto, redefined Neptune as a major force in the arrangement of the entire solar system. Astronomers now believe Neptune's gravity not only skewed the orbits of the small, distant bodies in the Kuiper belt but also affected the position of the giant gas planets. ➔

BY CURTIS RIST

"No one planet can tell us everything about the universe," says Heidi Hammel, a senior scientist with the Space Science Institute in Boulder, Colorado, "but Neptune seems to hold more than its share of information about the formation of our own solar system—as well as the solar systems beyond."

For decades astronomers have thought

tronomers now know that Pluto's orbit is strange only for a planet. It is perfectly normal for some 300 known objects in the Kuiper belt. To Renu Malhotra, a staff scientist at Houston's Lunar and Planetary Institute, these elliptical orbits have explanatory power: They suggest that Neptune—a planet with the mass of more than 17 Earths—influenced

called planetesimals. "What evolved was a sort of planetary game of handball, involving Neptune, Uranus, Saturn, and Jupiter," says Malhotra. By the rules of this interaction, Neptune literally tugged planetesimals from their orbits and "handed them down" to the giant gas planets closer to the sun. As the planetesimals moved into smaller orbits, they lost orbital energy and angular momentum—and that energy was instead absorbed by the planets. "The greater the orbital energy, the bigger the orbit," explains Malhotra. Neptune, Uranus, and Saturn began to move outward—with Neptune taking a 30 percent leap that moved it to its present location of roughly 2.8 billion miles from

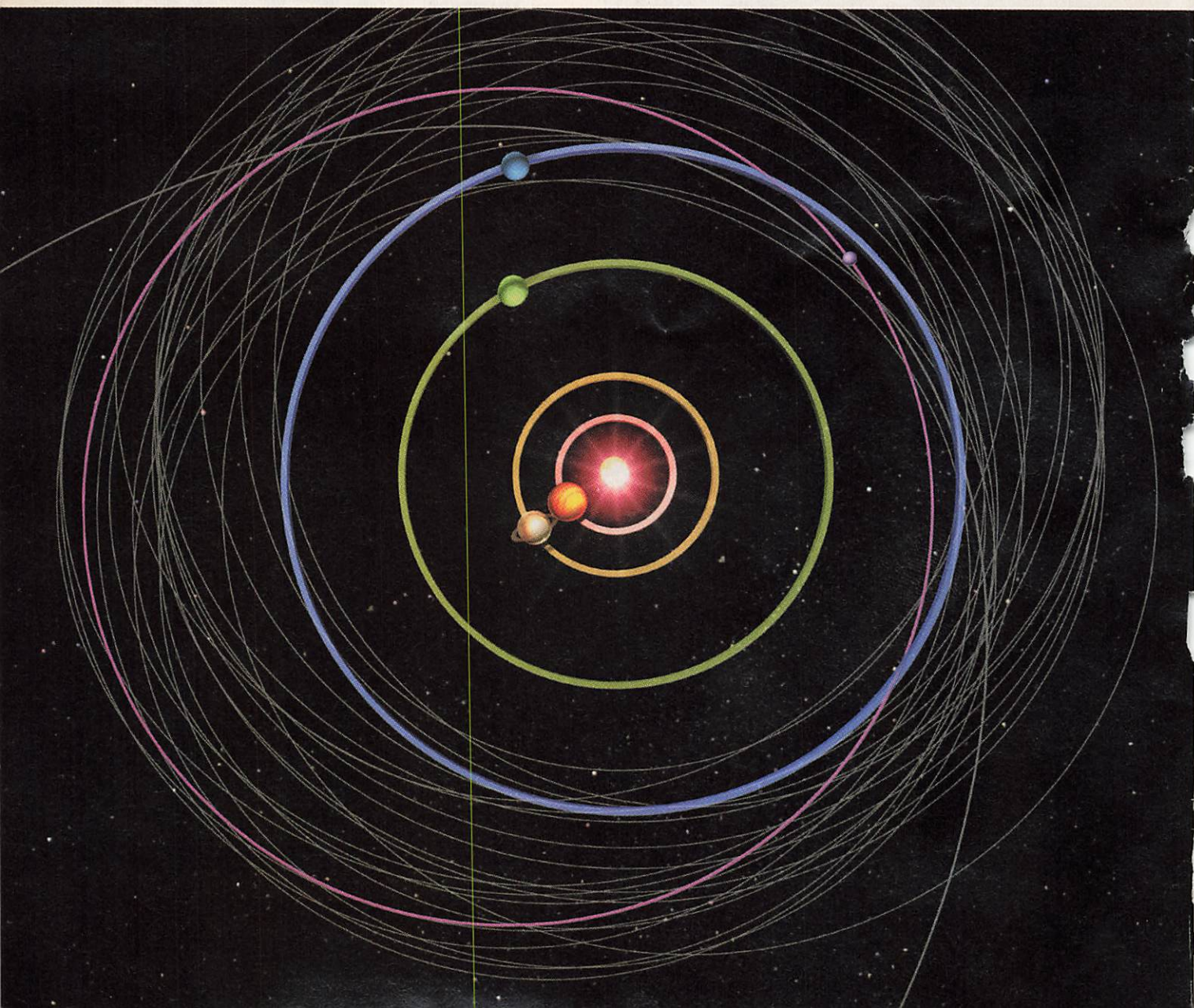
WHAT EVOLVED WAS A PLANETARY GAME OF HANDBALL INVOLVING THE GIANT PLANETS

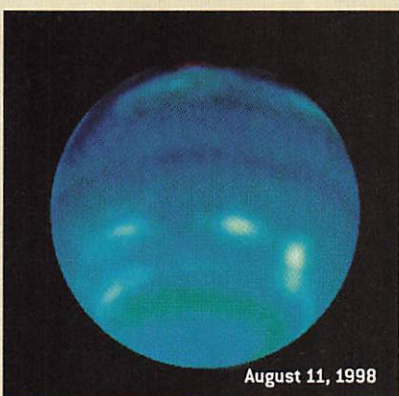
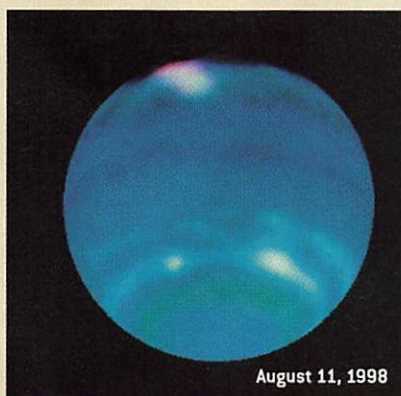
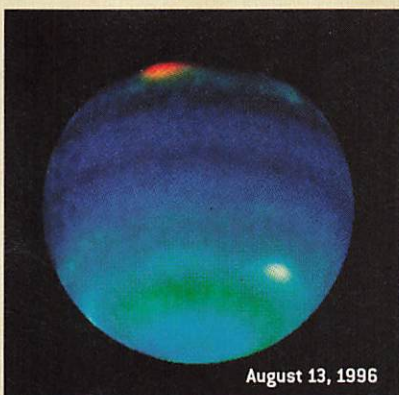
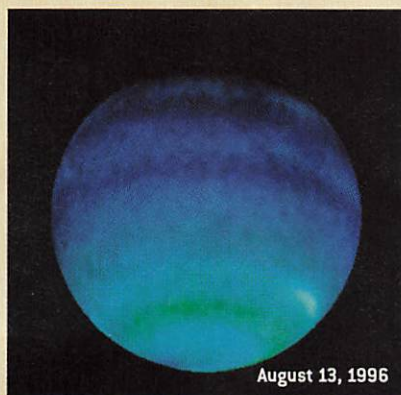
that planets remained stationary after the initial formation of the solar nebula. But something about Neptune's strange small neighbor, Pluto, tickled their curiosity. While the other planets travel in circular orbits, Pluto's orbit is a peculiarly tilted ellipse. As-

the orbits of all its diminutive neighbors.

How could this happen? The answer lies in the interactions that occurred during the solar system's early history. After the planets formed, their gravitational pull interfered with the orbits of leftover building blocks

THE GRAVITATIONAL PULL OF NEPTUNE SHEPHERDS PLUTO (PURPLE) AND HUNDREDS OF ICY OBJECTS IN THE KUIPER BELT (GRAY) INTO ELLIPTICAL ORBITS.





COLOR-ENHANCED IMAGES FROM THE HUBBLE SPACE TELESCOPE REVEAL NEPTUNE'S STORMY WEATHER. WINDS APPROACH 1,000 MILES AN HOUR AT THE EQUATOR, AND STORMS THE SIZE OF EARTH ITSELF CAN SWEEP ACROSS THE PLANET. METHANE IN THE UPPERMOST ATMOSPHERE ABSORBS LIGHT, MAKING THE PLANET APPEAR BLUE. THE PATCHES OF WHITE AND YELLOW INDICATE AREAS OF VERY HIGH CLOUDS.

the sun. Jupiter, which lay on the receiving end of the planetesimals, either absorbed or ejected them. As a result, Jupiter lost orbital energy, and its circuit around the sun shrank by about 2 percent.

Malhotra had theorized that Pluto's orbit had been shaped by Neptune, but it took the discovery of the Kuiper belt in 1992 to prove it. As Neptune glided outward, only those objects beyond a certain distance would have been able to escape being captured and pushed inward. Pluto, for instance, circles the sun two times for every three orbits of Neptune. Thus Pluto is said to be in a 2:3 resonance orbit with Neptune, says Malhotra, and other Kuiper belt objects have similar orbital relationships with Neptune. Any object orbiting closer than that, she believes, would have long been ripped from its circuit by the great planet. Pluto and the other objects in the Kuiper belt are just far enough away to avoid this fate.

Such planetary rearrangements appear to be common in other solar systems. The giant gas planet that orbits star 51 Pegasi, for

example, baffled astronomers when it was discovered in 1995. The planet was about the same size as Jupiter, but it orbited eight times closer to its star than Mercury does around our sun. "No gas planet could have formed that close to a star," says Malhotra, "so it had to have moved there." The theory by which Neptune and the outer planets may have moved gives one possible explanation for this—although there will inevitably be others, especially since the giant Pegasus planet must have moved inward, rather than outward like Neptune, Uranus, and Saturn.

The planetary movement of Neptune, strangely enough, may be relevant to Earth's development. One somewhat speculative theory holds that water came to Earth by way of a distant icy body—such as those found in abundance in the Kuiper belt and the more remote Oort cloud, an icy, comet-filled field. The outward movement of Neptune may have perturbed the motion of that ice-bearing body, sending it on a course that eventually caused it to crash-land on Earth.

But that's just one of Neptune's myster-

DESTINATION NEPTUNE

Because of Neptune's enduring mysteries, astronomers dream of getting firsthand information about the planet. The main problem is how to get a spacecraft to cover the more than 2.6 billion miles quickly.

Voyager 2 took just 12 years to arrive at Neptune, but it took advantage of a rare alignment of the outer planets that created something of a gravitational superhighway to the planet—a circumstance that won't repeat itself for another 200 years or so. Launched today, a similar spacecraft would have to travel the equivalent of the planetary back roads and wouldn't reach Neptune until 2030. "Nobody's interested in launching something that's so slow it won't arrive until after everybody who sent it up is either retired or dead," says John Brophy, a project manager at NASA's Jet Propulsion Laboratory in Pasadena, California. "And if it costs billions of dollars, nobody's going to want to pay for it, either."

Conventional rockets would be too slow and too cumbersome. And the thousands of pounds of fuel required would be prohibitively expensive. One speedy alternative is a spacecraft powered by ion propulsion—such as the type used on the *Deep Space 1* probe launched in 1998. Instead of combustible fuel, this spacecraft uses a much smaller supply of the naturally occurring gas xenon. By running an electric current from solar panels through the gas, "you can achieve a very high exhaust velocity—much higher than you can with a conventional rocket," says Brophy. Using this fuel strategy, the trip to Neptune might take only 10 years.

An even faster and far cheaper propulsion system could be devised using a solar sail. This technology involves rigging a spacecraft after it has been launched from Earth with an ultrathin, aluminum-coated plastic sail that is less than one twentieth the thickness of a human hair. "This is basically a mirror in space," says Charles Garner, a JPL engineer. As photons from the sun hit the sail, they bounce off—imparting up to double their momentum to the spacecraft. Blown by photons, a "sailcraft," as it's called, could travel as far as Neptune in as little as three years, says Garner.

What's more, he adds, the sailcraft could be deployed as reusable "slingshots." They could shuttle deep-space probes to the asteroid belt beyond Mars, hurl them into the great beyond, and then return to Earth's orbit to prepare for another mission. "When that's perfected, the cost of launching a probe would drastically fall," says Garner of the sailcraft ferry system. "It would open up a whole new era of deep-space and interstellar exploration." —C. R.



THIS IMAGE FROM *VOYAGER 2* SHOWS NEPTUNE'S GREAT DARK SPOT, A STORM SYSTEM THAT RESEMBLES JUPITER'S GREAT RED SPOT. THE KEY DIFFERENCE IS THAT NEPTUNE'S SPOT COMES AND GOES.

ies. When *Voyager 2* passed by the planet in 1989, it picked up images of a giant swirling storm the size of Earth that bobbed and weaved on the surface of the planet. Until then, nobody expected to find capricious storms on Neptune. Unlike the Great Red Spot on Jupiter, a turbulent region that has been observed since the days of Galileo, this storm proved unusually volatile: When the restored Hubble Space Telescope first took a look at Neptune in 1994, the dark spot had vanished. Changeable weather is no surprise

to Earthlings because the sun heats up our planet's surface and sends water vapor and air rising to create clouds and wind. Farther out in the solar system, however, the sun's energy is so minimal, its effect is supposed to be reduced by the law of inverse squares. "Since Uranus is twice as distant as Saturn, it receives four times less solar energy—and should have four times less climactic activity," says Carolyn Porco, a planetary scientist at the University of Arizona.

That law certainly seemed to be heeded

by Uranus, which was so devoid of clouds it looked like a great cue ball hovering in space when *Voyager 2* flew by. Most astronomers predicted an equally boring Neptune—which lies 30 times beyond the distance of the Earth from the sun. Boy, were they wrong.

First, Neptune proved to be a more brilliant blue than expected. Methane in its upper atmosphere absorbs red light, creating the blue effect. And frozen methane high in its atmosphere produces wispy clouds. Within Neptune's interior, a spherical shell of water sloshes around a solid core, throwing the planet's magnetic field off 47 degrees from its axis of rotation. None of this was as surprising as the discovery of storm systems. Near-1,000-mile-per-hour winds and ever-changing clouds "went against all the models of what had been expected, and we're still trying to understand the reasons why," says Hammel. "Since the energy is not coming from the sun, that leads to the question: Where is it coming from?"

Neptune itself must harbor the answer. Planetary scientists can calculate a planet's radiation balance—the amount of energy it emits compared to the amount of sunlight

A MISBEGOTTEN MOON

Great valleys studded with bulbous masses of ice cover Triton, Neptune's largest moon. And when the weak rays of the sun vaporize frozen nitrogen below Triton's surface, giant gas geysers rise miles high. "It's a landscape unlike anything we've yet seen in the solar system," says Bill McKinnon, a planetary scientist at Washington University in St. Louis. Once a freely orbiting object about twice the diameter of Pluto, Triton became ensnared in Neptune's gravitational pull. At first, Triton's travels around the planet would have been elliptical. But over millions of years Triton's orbital interactions with Neptune nudged the satellite into a circular orbit—and the frictional heat generated by the change caused Triton's interior to melt. "What followed was an intense period of geologic activity," which appears to have ended only recently, if at all, says McKinnon. Astronomers want a closer look at Triton's unusual geology and atmosphere—which many believe to be analogous to Pluto's. "That is the only way we'll get a glimpse into this alternative kind of geology and geophysics that all of the icy worlds present," says McKinnon. —C.R.

it receives—and Neptune's ratio is intriguing. "You've got great heat from the inside and very little heat from the outside, so you're not really in a stable situation at all," says Hammel.

Unlike Earth, which has only a very thin layer of atmosphere, a thick swath of gas surrounds Neptune's small solid core. In the outer layers of Neptune's atmosphere, the pressure would be similar to that on Earth, but with temperatures of -350 degrees Fahrenheit. Deeper into the planet, however, heat and pressure probably increase, until they rise so sharply that the atmosphere—much of it hydrogen—turns into a liquid state, "probably the consistency of pudding," says Hammel. Under these conditions, electrons become stripped from molecules, and the nuclei pack together. That is not a bizarre

methane in a pressurized chamber and used a laser beam to create "pressure and heat conditions that you might find about a third of the way toward the planet's center." Methane is composed of four hydrogen atoms that surround a carbon atom. Benedetti found that under extreme pressure the bonds holding the hydrogen atoms onto the carbon dissolved, and the carbon atoms began binding to one another. Under different conditions, carbon atoms would form a coal-like substance, but under this extreme pressure, they formed diamond dust. "We're not sure how big diamond crystals might form on Neptune," she says, but they could conceivably make the Krupp diamond on Elizabeth Taylor's finger seem like a chip. If those conditions exist on Neptune, it's possible that diamonds are literally raining down through

A HAIL OF DIAMONDS IN NEPTUNE'S INTERIOR MAY EXPLAIN ITS INTERNAL ENERGY

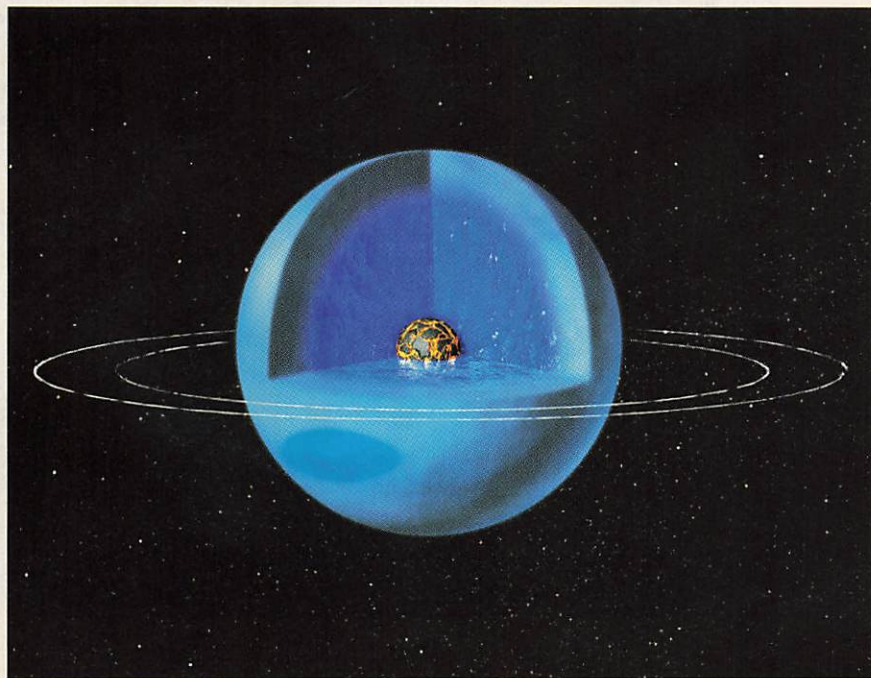
chemical configuration—it is the definition of a metal. "But it's unusual to think about hydrogen, which we know as a gas, being found in a metallic state," Hammel says.

Last year, a team at the University of California at Berkeley came up with a hypothesis about what might be occurring in the planet's atmosphere to explain Neptune's extraordinary internal energy. Robin Benedetti, a graduate student in physics, put some

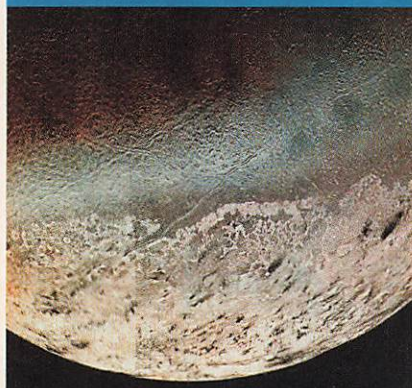
the atmosphere toward the planet's center, releasing heat as a result of friction. "This could be a really huge amount of energy," says Benedetti, and it may explain in part why Neptune radiates 2.6 times as much heat as it absorbs from the sun.

The actual answers to this and other new questions raised by Neptune will have to wait until the day an orbiter can be launched to collect more information. "We've come a long way in our understanding," says Hammel. "But until we get the sort of data that only an orbiter can provide, the best we can hope for is a blurry—but tantalizing—view of this amazing planet." 

GASES SURROUND NEPTUNE'S SMALL, SOLID CORE, AND THE ATMOSPHERIC PRESSURE MAY BE GREAT ENOUGH TO FORM A HAIL OF DIAMONDS. A SYSTEM OF FAINT RINGS OF DUST ENCIRCLES THE PLANET.



NEPTUNE'S STRANGE SATELLITES



Neptune's eight moons are an object lesson in the puzzles of the formation of planetary satellites—and none more so than the moon Triton. In the early days of the solar system, rocky material and icy debris were flying around, glomming together to form the planets. Eventually some became so large that their gravitational pull attracted gas and interplanetary dust as well. "As they did, they became almost like mini-nebulas and started spinning disks, which formed their own satellites—just as the formation of the sun spawned the planets," says Heidi Hammel of Boulder's Space Science Institute. When spawned by the planet it orbits, a satellite revolves in the same direction as the parent planet. The moon, for example, revolves in the same direction as Earth. But Triton revolves in the opposite direction from Neptune—a clear sign it was "captured" by the planet rather than formed within Neptune's own gaseous disk.

Nor is Triton the only puzzle. All planets have an area called the Roche limit in which the gravitational pull is so strong that material can't form into a satellite. Any satellite in the Roche limit must have either been captured or, more likely, dragged there by tidal forces on the planet's surface. Neptune has four satellites in the Roche limit—the only ones in the entire solar system. "All told—from Triton's retrograde orbit and the presence of four satellites in the Roche limit—there's something peculiar about the history of Neptune's satellites," says Carolyn Porco of the University of Arizona's Lunar and Planetary Laboratory.

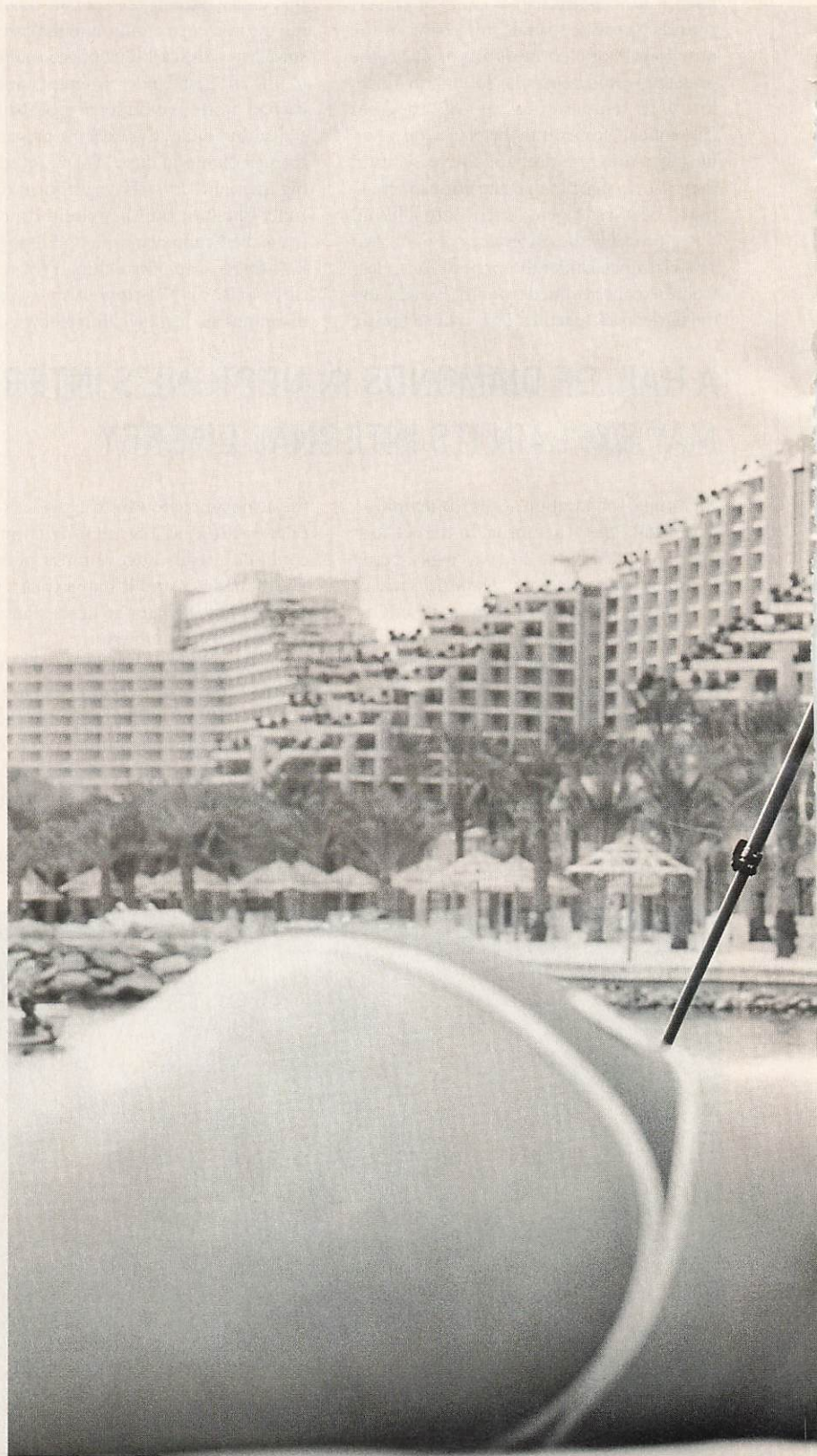
And the future could hold some surprises, too. "If you were able to bash up the satellites in Neptune's Roche limit today, you would have a ring system that would not look too different from Saturn's," says Porco. "So what we have here is a giant ring system waiting to happen." —C.R.

Photographs by Tom Stoddart

to save a • watering hole

By Mark
Cherrington

IF REUVEN YOSEF
DOESN'T WIN HIS FIGHT
AGAINST DEVELOPERS
IN ISRAEL'S HOTTEST
RESORT TOWN, HALF OF
EUROPE'S BIRDS
MIGHT DISAPPEAR





Eilat, Israel, is home to a booming tourism industry and some of the world's largest hotels. "This, for them, is blooming the desert," Reuven Yosef says. "I call it a true desert: a lifeless, monocultural thing."

ONE CLOUDLESS JULY AFTERNOON IN 1995, DALIT YOSEF AND HER 9-year-old son Erez left their home in Eilat, Israel, and set off for a nearby bird sanctuary. Their route took them down the hill through the bustling city, past brown stucco houses and apartment blocks, down streets lined with palms and tropical flowers. To the east, across the Red Sea, the Jordanian mountains rose in a stark palisade above Aqaba; to the south the desert mountains of Saudi Arabia were a dark shadow on the horizon. Yet Dalit took no comfort in the view. That idyllic locale had become an environmental battlefield.

On one side lay a legion of local developers, bent on turning Eilat into Israel's premier resort town. On the other side was Dalit's husband, ornithologist Reuven Yosef, equally determined to set aside part of the landscape for wildlife. The sanctuary that Dalit and Erez were visiting that day was ground zero. Economically, it was quite valuable: Among other things, the mayor had suggested turning it into a motocross track or a zoo. But biologically it was priceless. Every spring and autumn, a large part of Europe and Asia's migrating bird population—1.5 billion birds in all—passed through Eilat on the way to and from Africa. They stopped because the sanctuary was on the only land bridge between Africa, Asia, and Europe, and because it offered them the only food for hundreds of miles in any direction. Without the sanctuary, millions of the birds might die, and without those birds, ecosystems on three continents would be threatened.

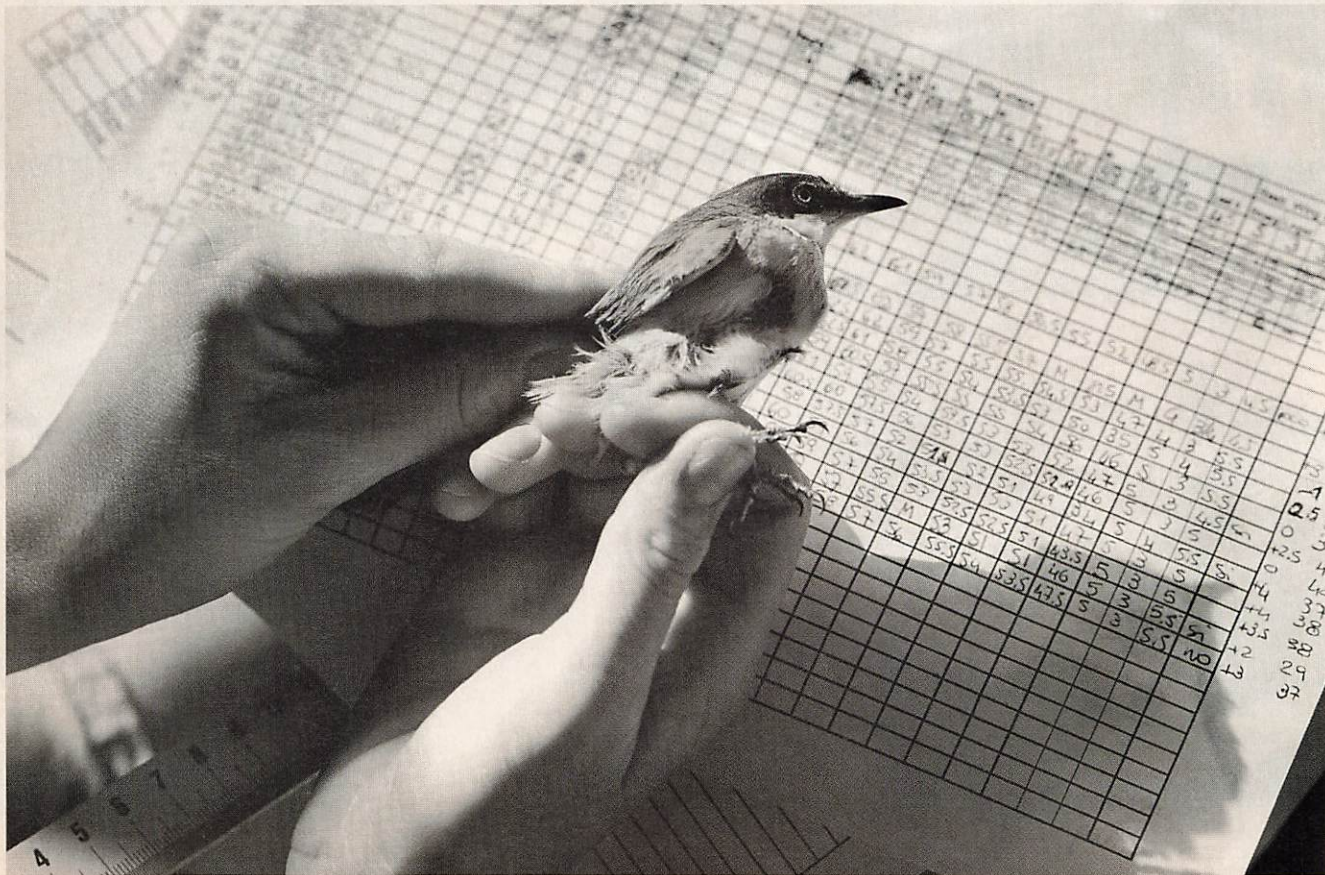
As director of the International Birding and Research Center in town, Reuven Yosef was attacking Eilat's developers publicly and relentlessly, fighting to keep bulldozers away from the sanctuary. But his opponents were just as vehement. For the past year, people had been calling the Yosefs' house anonymously, making threats. "If you

don't leave Eilat," they would say, "something really terrible is going to happen to your family." First one and then another of Reuven's jeeps was vandalized. At the sanctuary, fences were trampled, doors broken in, seedlings uprooted, and field equipment sabotaged so often that Yosef was spending 10 percent of his budget on replacement equipment. In each case, the culprits were never identified, and the police wrote off the attacks as "incidents of no public interest."

There was worse to come. When Dalit and her son reached the sanctuary that day in July, they walked through the trees to Reuven's research station, expecting to see the family dog, Jenny. Instead, as Dalit rounded the corner, she stopped in her tracks and screamed, spinning Erez around and covering his eyes. Jenny was hanging from her chain, which had been tied to the roof of the building, with a piece of paper tacked to her dead body. The words on the paper said, "Get Out!"

FOUR YEARS LATER, DESCRIBING THE INCIDENT, REUVEN YOSEF'S voice catches, then hardens. The pace of development has quickened, he says, and the attacks have escalated: A year after Jenny was killed, Yosef went to the sanctuary to find his research station burned to the ground. Yet he hasn't budged an inch. He is not a large man, but he is stocky and swarthy and black-bearded and radiates defiance. In his normal stance—feet planted apart and arms folded over his chest—

Below: Yosef and his students record extensive biometric data on captured birds—in this case, a *Sylvia* warbler. Opposite: Yosef lectures French students at his birding center in Eilat. His environmental activism has earned an extraordinary number of enemies. "I told him, you'd like to not have mankind here at all," says Rina Maor, the director for southern Israel at the Ministry of Tourism. "But we, mankind, are not less important."



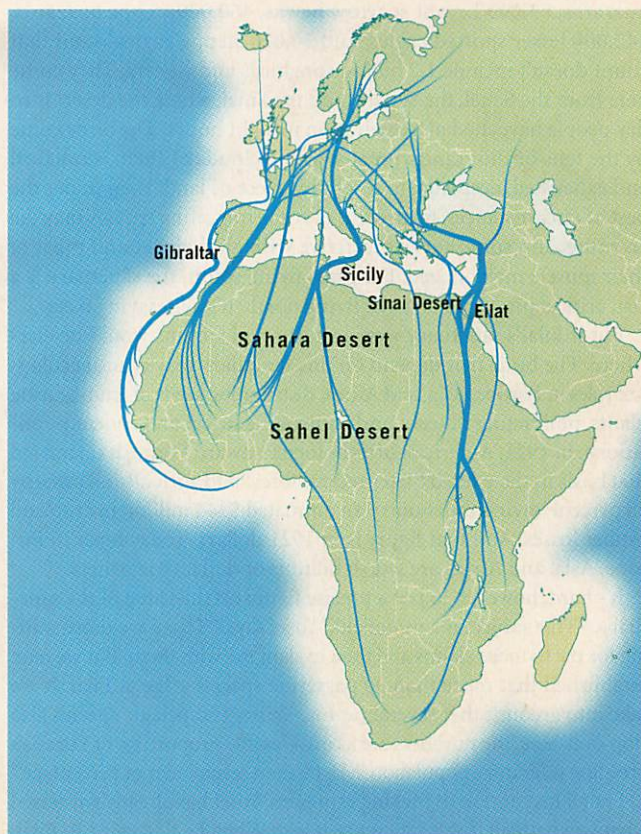


he wouldn't be out of place on the prow of a pirate ship. His black eyes are unflinching, and when he locks them on you, your instinct is to take a step back. His physical attitude suggests a falcon: compact, alert, fearless, and always prepared to hurtle headlong at his prey.

Yosef's zeal is equal parts personal and scientific, a function of both his upbringing and the gravity of the situation in Eilat. The son of a fighter pilot, educated in a military boarding school, he left his native India in 1974 at age 16, after the Yom Kippur War. "Being an Indian Jew, I was sort of brainwashed in the Zionist ideal that living in Israel is the thing for a Jew," he says, "so I wanted to come and give whatever I could." He soon landed in one of the Israeli army's elite units and was promoted to a high rank over the course of several extremely dangerous missions. But even then his loyalties were divided.

One day, during an excursion behind enemy lines, Yosef's unit came upon a stork riddled with shrapnel. Yosef wanted to evacuate it, but bullets and bombs were flying all around. So he and the unit's doctor huddled by a rock and worked for hours removing the shrapnel and dressing the wounds. From then on, Yosef says, "My unit knew that any animal that we found wounded in the field was treated.

Birds migrating between Africa and Europe use three major flyways. The western path crosses the Mediterranean over Gibraltar and is used by some 300 million birds. The central path goes by way of Sicily and is used by 200 million to 250 million birds. The eastern flyway, used by an estimated 1.5 billion birds, passes over Eilat, Israel. North of Yosef's sanctuary stretches 400 miles of Syrian and Arabian desert; south and west of it lie the Sinai, the Sahara, and the Sahel—1,200 miles of uninterrupted sand.



If we thought the animal could survive in the field, we released it, and if not, we brought it back and rehabilitated it." His men didn't necessarily agree with his approach, he says: "They humored me."

Yosef's compassion for wildlife—cultivated, he says, by an uncle who was an eminent zoologist—grew like a raging fire. "I realized back then the kinds of things that were plowed under in the name of human requirements, of Zionist ideals." After leaving the army in 1979, he got degrees in biology and education at the University of Haifa, earned his doctorate in zoology at Ohio State University, and went on to do research at Cornell under renowned biologist Tom Eisner. By the time he became director of the center in Eilat in 1993, he was equally adept at research and warfare: the perfect man for the job.

WALKING AROUND THE SANCTUARY THAT WOULD BECOME THE CENTER of Yosef's life—and nearly the cause of his death—one might wonder what all the fuss is about. The place is pretty enough. Tall, drooping jujube, or Christ's-thorn, trees shade bushes of sea blite, the primary plant for the birds, and dozens of other species. Two large

the marsh that birds once used here was being built over. "You would see birds wandering around town, exhausted and looking for food," he says, "but all that was planted were exotic species." Some of the birds were feeding in local, pesticide-laden farmlands.

There wasn't much point in directing a birding center if it meant watching birds die, so Yosef threw himself behind a local initiative to build a bird sanctuary. A local bird lover and former deputy mayor named Shmulik Tagar had scouted out a possible location for the sanctuary at an abandoned 160-acre landfill on the edge of town. Yosef helped Tagar persuade the town to donate the land, then the two men talked the town's developers into taking the topsoil they were excavating and dumping it onto the landfill. Rather than fight for a share of Eilat's precious water supply, the activists went after the town's sewage, then being dumped raw into the Red Sea. They knew that the sewage, in time, would kill one of the city's major sources of income: its spectacular coral reef. So they helped organize demonstrations and bumper-sticker promotions. After three years, the town agreed to build a treatment plant just above Yosef's land.

LAST DECEMBER A GOVERNMENT OFFICIAL CHARGED YOSEF WITH BEING ANTI-ISRAELI. ALTHOUGH HE WAS EVENTUALLY CLEARED, HIS ACCUSER HAD NO LACK OF ALLIES

ponds are dotted with rocks and islands, and the islands are covered with more sea blite. But compared with other exotic and embattled wildlife areas like the Amazon, Madagascar, and the Serengeti, Eilat's sanctuary seems unremarkable. What could be so critical about it?

The answer lies in Yosef's stunning statistics. Every spring, he estimates, 3 million raptors pass over Israel, including 800,000 honey buzzards, 65,000 Levant sparrow hawks, 460,000 steppe buzzards, 142,000 lesser spotted eagles, and 30,000 steppe eagles—and that count doesn't include 1.2 billion songbirds and waders. They come here from the Sahel, the Sahara, and the Sinai, where the desert is so dry people have died of dehydration in eight hours. The birds come by the tens of thousands, great swirling clouds of them, sunbaked and exhausted, desperate to reach this piece of land. Even under the best of circumstances, 60 percent of some migrating species may die en route, and some survivors arrive with all their fat and most of their muscle metabolized. For birds flying south, the sanctuary is a last, critical pit stop. For birds flying north, it's a lifesaving oasis.

But if Eilat's sanctuary were lost, the real victims would be elsewhere. The birds that depend on this sanctuary play crucial ecological roles in Europe, Asia, and Africa, distributing seeds of fruit-bearing plants, pollinating flowers, and controlling insect and rodent populations. In 1921, American ornithologist Edward Forbush calculated that birds in the United States reduce forest and agricultural pests by 28 percent, saving the country an estimated \$444 million in crop and timber losses. And that figure is in 1921 dollars. Today birds in Europe, Asia, and Africa are worth billions of dollars to farmers.

It's hard, however, to put a precise figure on the value of the sanctuary. "This subject is a minefield," Yosef says. "There are those waiting for me to make claims and then to slam me with them. But we have established that more than 90 passerine species stage at Eilat. If we take into account that several raptor, wader, and pelagic species also stop over here, the numbers are a considerable proportion of Eurasia's breeding migratory population. Maybe even several tens of percentage."

For all his caution in making estimates, Yosef has already witnessed what will happen if this sanctuary is lost. When he first came to Eilat,

The rest was easy by comparison. Using a backhoe, Yosef dug two ponds and a drip-irrigation network. Then he raised money to buy plastic tubing, set up a solar pump, and pulled down some of the nutrient-rich treated water from the sewage canal that ran alongside his land. Finally, he convinced the Jewish National Fund to help him seed all the native plants that had grown in the original salt marsh. Today his garbage dump is an ornithological paradise. Only one twentieth the size of the original marsh, it supports a far greater density of plants, and even more food for the birds, thanks to irrigation.

IN MOST PLACES, SUCH AN ACHIEVEMENT WOULD MAKE REUVEN YOSEF a hero. But Eilat is a one-business town, and that business is tourism. Over the past five years, the overall number of hotel rooms has doubled, to 10,000, and the population has leaped from 45,000 to 90,000. There are millions to be made developing the desert, and 160 acres of natural habitat in the heart of it seems to many like land wasted.

Driving through town one afternoon, Yosef launches into what must be a well-worn tirade against the appalling environmental cost of Eilat's boomtown mentality. Those flowers and waving palms along the streets are all exotic species, he says. They are displacing native plants and animals. Those glass-bottomed boats are destroying the coral on which they make a living. "When I told them they had to think of future generations," he says, "they told me, 'Let them worry about their own problems; I'm going to make my money now.'"

Yosef's opponents, for their part, make no apologies. "When I was born, in Tel Aviv, there were fewer than 1 million people here," says Rina Maor, the director for southern Israel at the Ministry of Tourism. "And now we are 6 million. Yes, we pollute, we do. What can we do? We don't live in tents. I know that we disturb not only the birds but also the corals and fish, and we are not so nice, we human beings—we are sometimes very cruel. But what can we do?"

Yosef threatens much more than a few hotel builders, it seems; he challenges the very idea of Israel. More than 50 years ago, the country's founder and first prime minister, David Ben-Gurion, declared that Israel's mission was "to make the Middle East bloom again." As

a Jewish nation, Ben-Gurion believed, Israel would gain credibility only if Jews established an undeniable presence. In Israel, making the desert bloom has been both a political and a cultural obligation.

On paper, Israel appears to be protecting its environment: Nearly a quarter of its land is set aside as national parks or nature reserves. But 63 percent of those reserves are less than half a square mile in area. Moreover, half of the official preserves are on land used by the military. The Ministry of the Environment can create a reserve only if the Ministry of Agriculture or the Ministry of Defense approves. Finally, because the government technically owns all the land in Israel, any given piece can be confiscated and reclassified at any time.

"Israel's got this paradox," says Alon Tal, who has just finished a book on Israeli environmental history. "We have remarkable biodiversity for a country this size because of our location on three continents. I mean, in my backyard we've got hyenas living with wolves and foxes, all in the middle of the desert. The trouble is, our population is growing very fast and the standard of living is growing very fast. We've got a developing country's demographic profile with a Western country's economic profile. And that can lead to a lot of problems."

LAST DECEMBER A GOVERNMENT OFFICIAL CHARGED YOSEF WITH being anti-Israeli. Although he was eventually cleared in a hearing, after dozens of scientists and friends from around the world came to his defense, his accuser had no lack of allies. Just this past winter, Yosef mounted the barricades again when the Israeli government, as part of a peace agreement with Jordan, proposed a new international

Yosef prepares to release a steppe buzzard after banding its leg. Every spring, he estimates, 460,000 of these buzzards pass over Eilat.

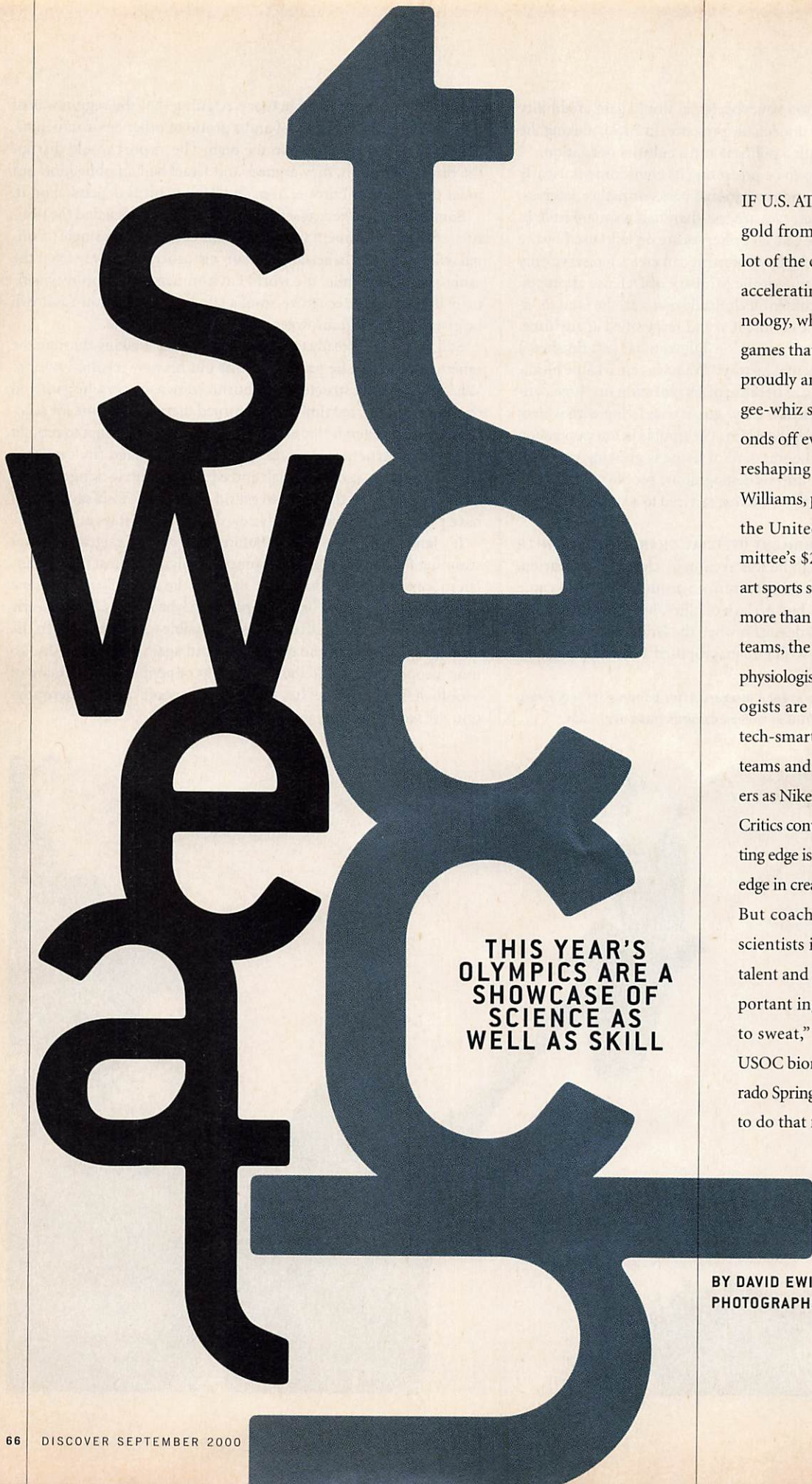
airport not far from his sanctuary. Arguing that the region was of unique biological value, Yosef and a group of other environmentalists petitioned for a change in the plan. The airport would disrupt the birds' migration, they argued, and Israel had an obligation not to let that happen: Europe, Asia, and Africa's birds depended on it.

Somehow, it worked: Yosef and his colleagues persuaded the minister of the environment to take up their cause. Only a single terminal will be built in Israel, and that on disturbed land away from the sanctuary. Meanwhile, the world environmental community is finally beginning to recognize Yosef's efforts. Next month, Yosef will be given the prestigious Rolex award for conservation.

Still, he is hardly ready to let down his guard. Walking through the sanctuary one day, he proudly points out his new research station. When the original structure was burned down, he says, he gathered the building's charred timbers and turned them into seating for sanctuary visitors. Then he launched a fund-raising campaign to rebuild it. The new structure is made of chemically treated fire-resistant wood. It's set on a concrete slab and equipped with locking shutters for the windows. "If they want to get rid of this one," Yosef says, "they'll have to drop a bomb on it." His new dog, though, stays at home.

It's January now—the calm before the storm of migration—but scanning the sky, Yosef notices something flying against the Jordanian mountains in the distance. "Oh, look," he says. "There are some ducks coming in. Looks like mallards, or maybe pintails. They're early this year." Even with binoculars it's impossible to see them. Then the birds pass in front of the mountains and against the clear sky. To most people, they would look like grains of pepper at the far end of a football field. But Yosef has uncommonly good vision: Where anyone else would see only desert, he sees birds. ☒





THIS YEAR'S
OLYMPICS ARE A
SHOWCASE OF
SCIENCE AS
WELL AS SKILL

IF U.S. ATHLETES BRING HOME gold from the Sydney Olympics, a lot of the credit may be owed to the accelerating presence of high technology, which is radically remaking games that just a few years ago were proudly amateur and lacking in the gee-whiz science that can shave seconds off event times. "Technology is reshaping most sports," says Lance Williams, program administrator at the United States Olympic Committee's \$2.2 million, state-of-the-art sports science division. Employing more than 25 people to assist 45 U.S. teams, the division's biomechanists, physiologists, engineers, and psychologists are augmented by dozens of tech-smart specialists on individual teams and at such equipment makers as Nike, Adidas, and GT Bicycles. Critics contend that technology's cutting edge is fast overtaking the human edge in creating stellar performances. But coaches, officials, and sports scientists insist that old-fashioned talent and grit remain the most important ingredients. "You still have to sweat," says Jeffrey P. Broker, a USOC biomechanist based in Colorado Springs. "No technology is going to do that for you." Not yet anyway.

BY DAVID EWING DUNCAN
PHOTOGRAPHS BY RAIMUND KOCH



SLIP SLIDING AWAY

When U.S. breaststroker Ed Moses flings himself into the cornflower-blue water of the Sydney International Aquatic Center, the only skin showing will be on his face and below his elbows and knees. Looking like a sleek Teletubby in his Teflon-coated, formfitting bodysuit, Moses will glide through water with greater efficiency and more speed than did former Olympians clad in skimpier suits. His Adidas-made supersuit is designed to put pressure on appropriate spots on the body to maintain proper technique. The tight-fitting fabric around his biceps and thighs reduces muscle vibration, and hence fatigue.

IT'S IN THE BAG

Olympian boxer David Jackson's punch power is measured using an instrumented heavy bag, exclusive to the U.S. team, which looks like a normal punching bag. Except engineers at the USOC workshop in Colorado Springs have embedded a PVC pipe inside running the length of the bag. It houses a device called an accelerometer, a three-inch wafer of circuitry and wires that translates the pounding of a jab or a hook into schematics displayed on a computer screen.

Videotape shot while the boxer bashes the souped-up bag is run on the same screen in tandem with numbers and graphics, a juxtaposition that allows coach and athlete to critique the athlete's punch effectiveness—his stance, arm motion, and attitude. "I think the boxers are getting stronger and better because of this bag," says David Lubs, director of programs for the U.S. boxing team.

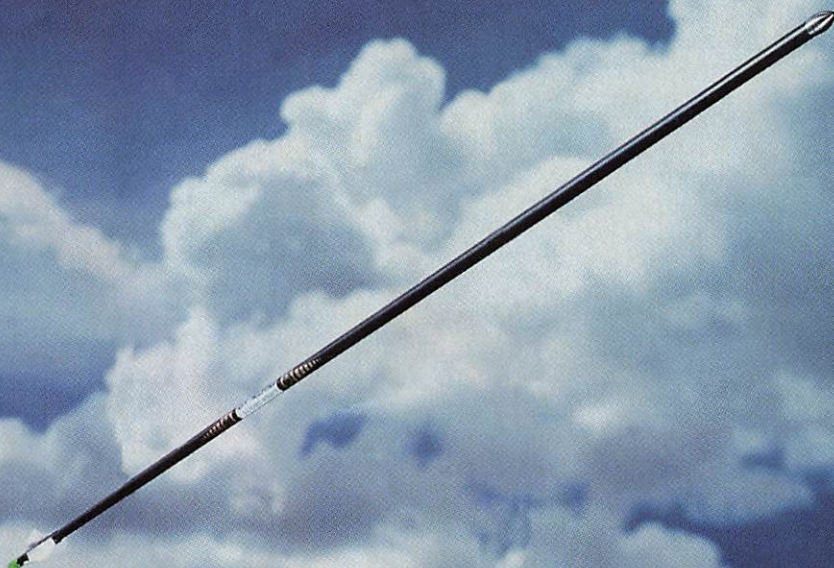


PIERCING THE WIND

Come September in the down-under world of Sydney, the air blows with ferocity, averaging 24 miles per hour. At nearby Homebush Bay, where archers will compete, winds frequently gust up to 50 mph. Such force can play havoc with a slender shaft zipping along at more than 130 mph toward a target 230 feet away.

"Oh, baby, the wind was impressive," says Don Rab-ska, a former archer and the coach of movie-star archer Geena Davis, who competed in an Olympic test tournament in Sydney a year ago. "On one of the practice days, when I was standing with Geena, I was literally blown off the line. It was howling!"

To help the arrows fly true, U.S. archers will be using weeny one-fifth-inch diameter shafts weighted in the front with heavier-than-steel tungsten points. Manufactured by Easton Archery of Salt Lake City, Utah, the X-10 arrows are made from the latest aluminum-carbon hybrid, with slippery carbon-graphite coatings that help reduce drag.



STRAIGHT SHOT

Last January Olympic shooter Bob Foth was off his usual mark while firing his .22 caliber rifle in the prone position. To find out why, he visited engineer Tim Conrad at the U.S. Olympics Center in Colorado Springs. Conrad clipped a tiny 120-gram diode laser to the bottom of Foth's weapon.

As Conrad demonstrates, when the weapon is fired, a laser beams along the exact trajectory of the bullet as it zings at 750 miles per hour to the target, situated 50 meters (165 feet) away. The beam is concentrated to strike at the bullet's exact point of impact.

The laser is used concurrently with videotape to check shooters' aim before and during a shot and how much they sway while pulling the trigger. Heart monitors strapped to the gunners' chests also measure the impact of pulse rates on accuracy. For optimal results, shooters must remain as still as a stone while firing; one minute of arc can make the crucial difference between a gold medal and no medal at all.

For Foth, a three-time Olympian, the lasers revealed that his stance, pulse rate, and gun harness were fine. The trouble was that his ammunition was firing slightly off: "Using good ammo, he improved," says Conrad.





I'M GONNA LEARN HOW TO FLY

For the pole vault, biomechanists are testing the bend and verticality of poles in an effort to further thwart gravity. They videotape vaulters and use the tape to build computer models that analyze the bend and motion of poles and the style and placement of the athletes in order to help heave humans ever higher.

The garb worn by track-and-field athletes has undergone some radical remodeling to enhance performance. When Florence Griffith Joyner broke the world record for the 100-meter dash, her body was moving at close to 22 miles per hour. But her legs whipped back and forth at up to 50 mph. "The legs are in a different airflow environment, so we are focusing on making the legs more aerodynamic," says USOC biomechanist Jeff Broker. This year in Sydney some runners and jumpers will be wearing special bodysuits by Nike that will cut down on the wind resistance of skin against air, with the possibility of improving times by valuable fractions of seconds, depending on the competition.

To cut times in sprint and hurdle events, athletes' shoes have been pared away so that they now amount to lightweight "socks with spikes attached," according to triple-jump coach Dick Booth. At Sydney, his jumpers plan to use another innovation: ultralight spikes made of ceramics rather than metal that help launch athletes off the rubber tracks more easily and efficiently.



EVERYTHING OLD IS NEW AGAIN

At the 1996 Atlanta Olympic Games, cyclists with teardrop-shaped helmets and ultratight bodysuits rode machines only vaguely resembling anything hitherto called a bicycle. As if tiny front wheels, ultralight Kevlar frames, and almost paper-thin chain casings and tubes were not enough, engineers of the SuperBike also placed the handlebars so radically far forward that cyclists crouched with buttocks high in the air, thus reducing wind resistance and cutting some times by several seconds. The SuperBike stirred an uproar—few teams could afford its high price—and the Union Cycliste Internationale, the sport's governing body, banned it from competition.

In Sydney, the old bicycle—or something very close to it—is back. According to the UCI's regulations, cycles must have a diamond-shaped frame, equal-sized wheels, and handlebars closer to the oldfangled, upright position. Many U.S. Olympians will be riding GT's new SuperBike III (the 1996 SuperBike was actually number two in the series), a machine that pushes the UCI regulations to the max. Although it looks like the older "bike," it has a more aerodynamic frame and silk tires pumped to 250 pounds pressure per square inch. U.S. cyclists also will be wearing improved suits with the seams sewn out of the airflow to reduce friction. The slipperier-than-skin suits may cut times by as much as one to three seconds.



STICKING TO YOUR OARS

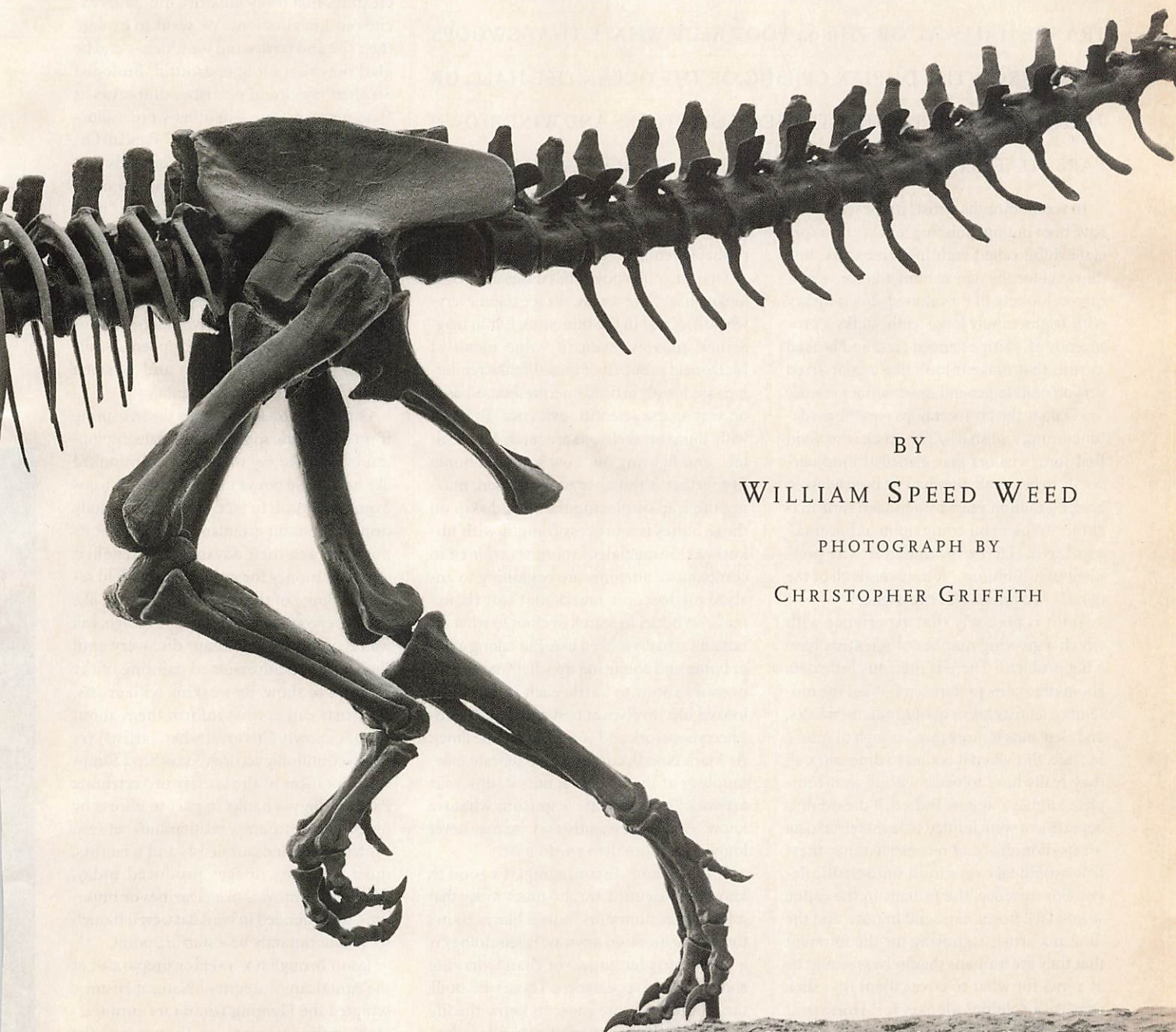
To train Olympic eight-person rowing crews, scientists mounted a plastic box the size of a paperback book and weighing just 1.4 pounds right behind the coxswain's seat. As muscles strain and water spews in a spray from the ends of the oars, the box pings a signal that relays sensor-collected data through a small antenna to a fancy laptop on the coach's boat.

Attached to the oars and their mechanisms, the sensors help create a biomechanical profile of each crew member's contribution to the boat's speed and acceleration. "We are looking for force, power, curve, and synchronicity," says USOC biomechanist Jeff Broker. The sensors assess each oar's force and angle, producing charts that reveal who is pulling more than the others. ☐

[WHAT DID DINOSAURS REALLY LOOK



LIKE...AND WILL WE EVER KNOW?]



BY
WILLIAM SPEED WEED

PHOTOGRAPH BY
CHRISTOPHER GRIFFITH

Skeletal reconstructions, including an allosaurus on display at the American Museum of Natural History, can only hint at what dinosaurs looked like in the flesh.

IN A LUMINOUS TOP-FLOOR WORKSHOP CLOSED TO THE PUBLIC AT THE AMERICAN MUSEUM OF NATURAL HISTORY IN NEW YORK CITY, ARTISTS WORK WITH SCIENTISTS TO RE-CREATE SCENES FROM LOST OR VANISHING WORLDS. THIS IS THE BIRTHING ROOM FOR THE MUSEUM'S ELABORATE DIORAMAS, SUCH AS THE BRACE OF NORTHWEST INDIANS WHO AIR-PADDLE THEIR CANOE THROUGH A FLUORESCENT ENTRANCE HALLWAY, OR THE 94-FOOT BLUE WHALE THAT SWOOPS DOWN FROM THE DUPLEX CEILING OF THE OCEAN LIFE HALL, OR THE HERD OF ELEPHANTS WITH FEARSOME TUSKS AND WINDBLOWN EARS THAT CHARGES THROUGH THE HALL OF AFRICAN MAMMALS.

In recent months, artists in the workshop have been putting finishing touches on a special exhibit called Fighting Dinosaurs. In a diorama for the new exhibit a fierce velociraptor, looking like a thinned-down turkey with frighteningly large teeth, stalks a protoceratops. With a flanged crest and beaked mouth that make it look like a goat-sized version of its larger and more famous cousin, *Triceratops*, the protoceratops sees the predator coming and snarls. The scene is so vivid that some visitors may glance around nervously to be certain they haven't been whisked back 80 million years by a hidden time machine. "When you come upon a diorama," says David Harvey, the museum's vice president of exhibitions, "it transcends all of the data. It becomes a real experience."

Yet it is precisely that experience with which a growing number of scientists have a big problem: There is precious little data about dinosaurs to transcend. What the museum scientists know about Indians, whales, and elephants is more than enough to mimic real life. But when it comes to dinosaurs, all they really have to work with is an incomplete jumble of bones. Indeed, if the exhibits department were limited to just skeletal data for its dioramas and reconstructions, these halls would take on a most unromantic flavor. For instance, the Indians in the canoe would lack noses, ears, and breasts, and the diorama artists (ignoring for the moment that they are humans themselves) would be at a loss for what to cover them in—slick skin like a dolphin? Monkey fur? Horse pelt? As for the blue whale, no one would know to make it blue. And the elephants are a special case. There's a running joke among

professional dinosaur artists that goes like this: Given just an elephant skeleton, they'd probably render a titanic hamster.

Does anyone know what dinosaurs really looked like? Sure we do. We see them everywhere, not just in the museums, but in magazines, movies, even in value meals at McDonald's. But all of these lifelike renderings are mostly artistic interpretations based on very sparse scientific evidence. To begin with, dinosaur skeletons are rarely found intact, and figuring out how scattered bones fit together is not always clear. Then, making the leap of placing tissue and skin on those bones is a process fraught with unknowns. Some paleontologists trained in comparative anatomy are beginning to analyze microscopic marks that soft tissues make on bones in search of clues to what dinosaurs actually looked like. But taking a pile of bones and conjuring up what snarling dinosaurs about to battle each other really looked like involves at best equal parts educated guesswork and complete artistic fancy. As Mark Norell, curator of vertebrate paleontology at the museum, puts it, dinosaur artwork "is a fantastic leap from what we know." And most scientists say we may never know a lot more than we do now.

If that seems discouraging, it's good to know that scientists are also quick to say that asking what dinosaurs looked like is asking the wrong question anyway. Paleontology is a much broader endeavor than worrying about outward appearances. Those who study dinosaurs are more eager to know the life histories of the beasts: what particular adaptations they had, how they ate, how they raised their young, and what evolutionary

relationships they might have had with one another and with modern-day animals. Time-traveling visual imagery grabs the public's attention, but it's not the point. "Dinosaur entertainment is healthy, sure," says Luis Chiappe, a paleontologist with the Natural History Museum of Los Angeles County. "But we don't look at *Batman* and think it's a documentary about the LAPD."

Further, to blame the artist is also to blame the messenger. Dinosaur art pervades our culture because we want it to. As fantastic creatures that really did exist, dinosaurs excite our imaginations. We want to explore their size and power and weirdness—and be glad they're no longer around. Biologist Stephen Jay Gould describes dinosaurs as "big, fierce, extinct—in other words, alluringly scary, but sufficiently safe." Randall Osborne, a social psychologist, contends that our need to imagine creatures vastly more powerful than we are is so strong that, "if we hadn't discovered dinos yet, we would have invented them ourselves. We would have made them in our movies." Or in our mythology: The Loch Ness Monster, Chessie the monster of Chesapeake Bay, and the various fire-breathing dragons that cropped up millennia ago in both Eastern and Western mythology are hardly accidental.

Our attraction to dinosaurs doesn't spring from a scientific source, so the paleontological inability to say what they really looked like has no real power to drive dinosaur icons from our world. In fact, rather than wholly dismiss dinosaur art, many scientists use its popularity to their advantage. After all, it does win money for museums and field research. Some of the more media-savvy, like Paul Sereno at the University of Chicago, will wait to publicize a dinosaur discovery until they have a commissioned painting of the creature to show. By working with artists, scientists can at least inform them about what is known. "It's great when [artists] try to be scientifically accurate," says Scott Sampson, an officer of the Society of Vertebrate Paleontology. Thanks in part to efforts by his group to encourage relationships between professional dinosaur artists and scientists, most dinosaur images produced today, whether for movies or magazines or museums, are grounded in hard data, even though hard data can only be a starting point.

Jason Brougham, a senior preparator at the American Museum of Natural History, sculpted the Fighting Dinosaurs' protoceratops in the new diorama. To start with the science, Brougham studied protoceratops bones under the direction of paleontologist

Norell. Brougham had a lot to go on because some 120 protoceratops skeletons have been found. For some dinosaur species, the fossil record contains only one skeleton, which is, more often than not, incomplete. Many dinosaur artists have faced the challenge of rendering a creature on the basis of half a skeleton. Mark Hallett, who has drawn and painted dinosaurs for museums, scientific publications, *National Geographic*, and movie studios, recently rendered a newly discovered dinosaur, *Seismosaurus*, on the basis of only 40 percent of its skeleton: "A few neck vertebrae, a complete pelvis, about a third of the tail, and no skull," he says. To help get a better idea of what the creature looked like, Hallett studied its closest known relatives and made a plausible guess.

Even with complete skeletons, there is lots of room for interpretation on how the bones go together. One major controversy with ceratopsians (the family of *Triceratops* and *Protoceratops*) is whether they stood on straight legs like rhinos or crouched crook-legged like crocodiles. In most dinosaur art before the 1980s, ceratopsians dragged their bellies under legs crooked out to the sides. Since then, it has been more popular to render them straight up, as on rhinos. That is the way Brougham sculpted his protoceratops. But Peter Dodson, a ceratopsian expert at

the University of Pennsylvania, argues the proper pose is crook-legged, not necessarily in the "extreme push-ups" pose of modern crocodiles, but certainly not in the straight pillar fashion of modern rhinos either. According to Dodson's reading of bones, all straight-legged ceratopsian reconstructions suffer from painful shoulder dislocations.

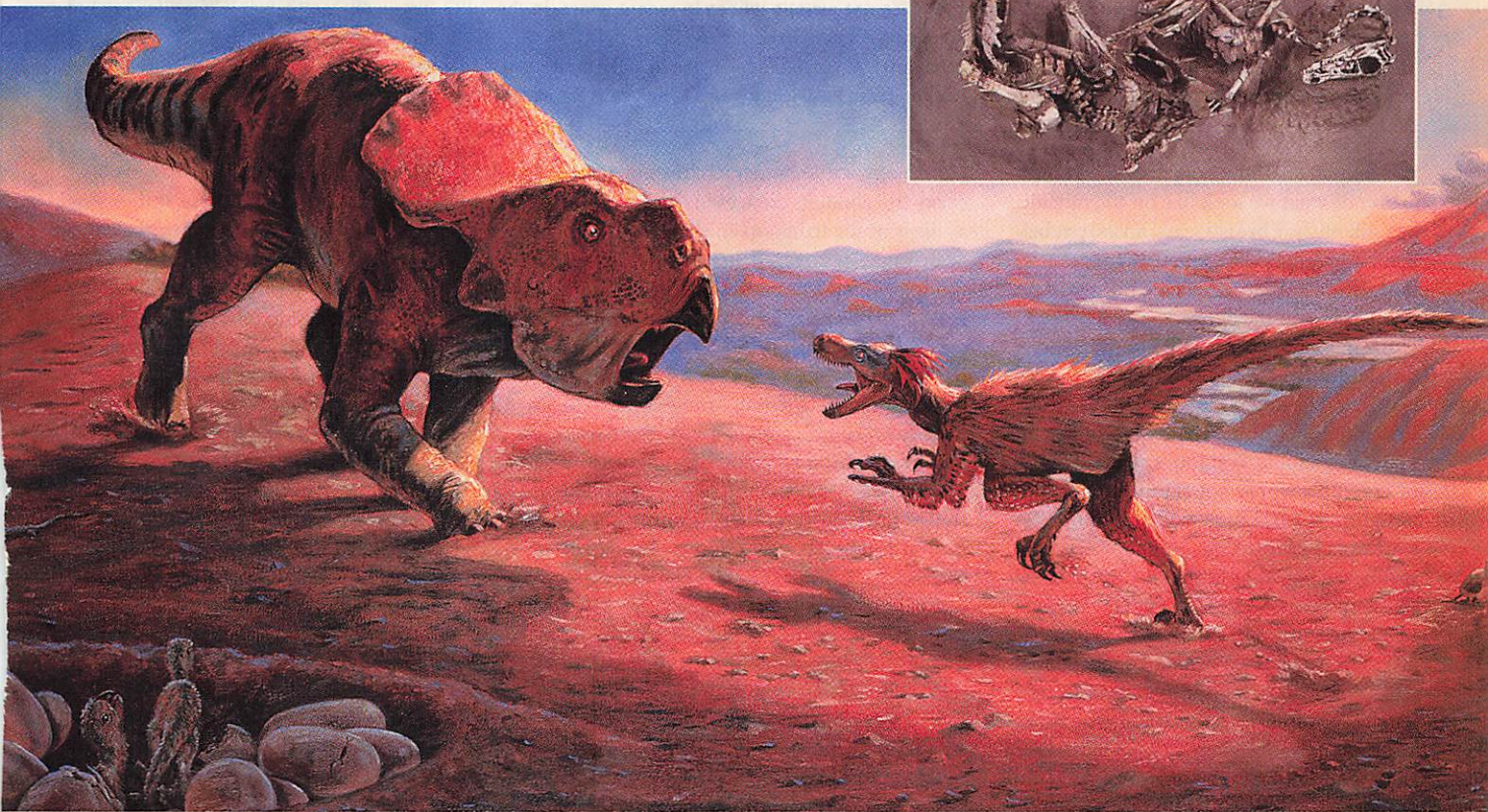
With a working model of the skeleton, artists like Brougham must first think about muscles. The bones help in this regard. Muscle attachment points are sometimes obvious as scars on fossils, and the relationship between muscles and bone is fairly consistent for most vertebrates.

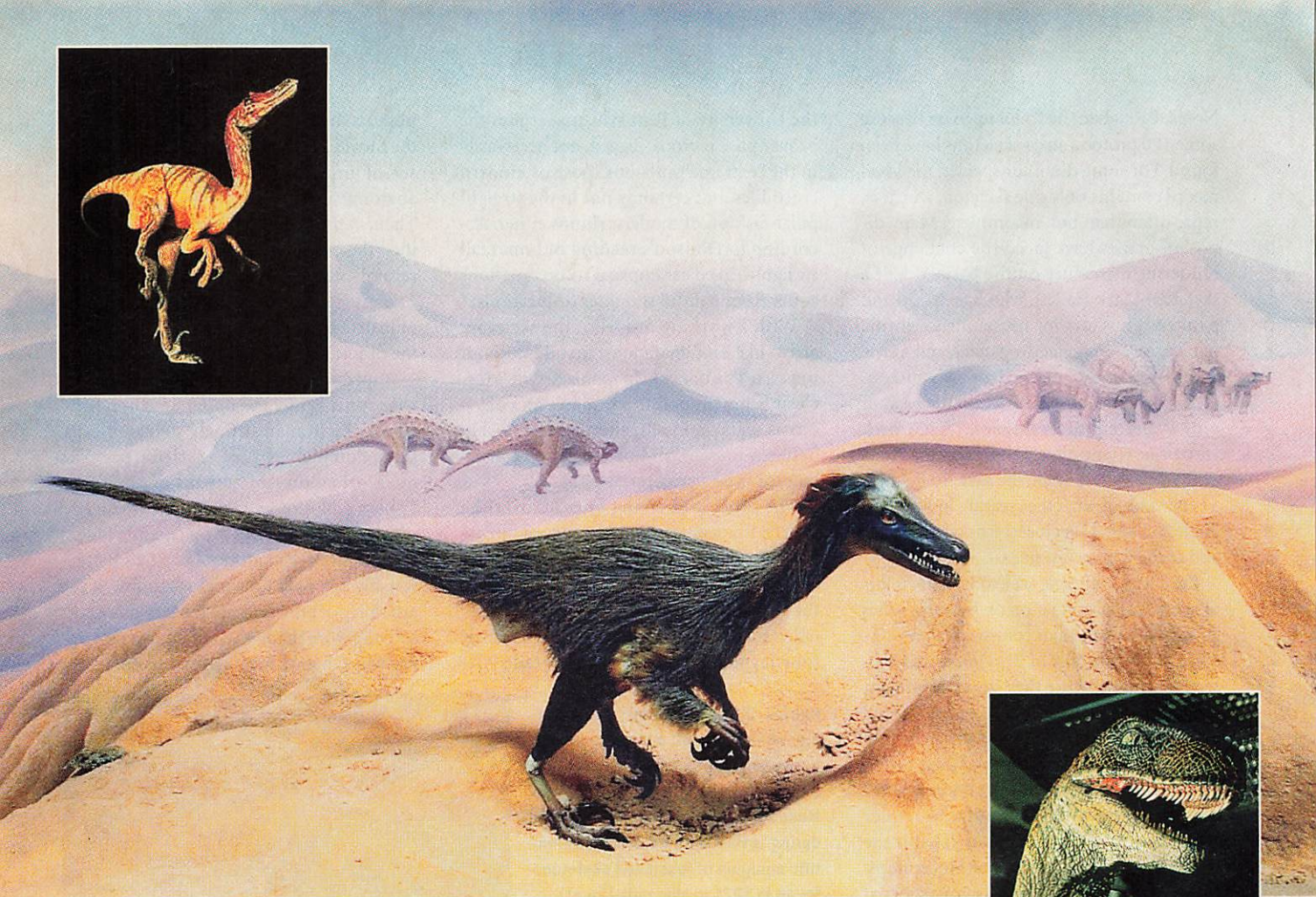
The process of laying muscles over the skeletal frame was vital to the success of Disney's *Dinosaur* movie. Hallett put together some of the initial working illustrations of these imaginary dinosaurs. He sketched detailed skeletons of iguanodons, the herding, four-legged, long-necked, long-tailed di-

nosaurus that serve as the main characters in the movie. Over each skeleton, he drew a full set of muscles adapted from crocodile anatomy and complete with Latin names. Then, at the behest of Disney, Hallett modified the overall look of the creatures to be reminiscent, in a Mesozoic way, of horses. The muscle drawings became the basic set of instructions the animators used to move the dinosaurs around in a believable way.

Applying muscles to a skeleton can be error prone. While the upper arm bone and elbow of a human strongly suggest biceps, the abdominal cavity of a skeleton provides no information—in humans or dinosaurs. "There's a lot of extrapolations involved," says Hallett, but if you are a careful student of comparative anatomy, "you can be reasonably assured of the major groups." If the artists render the muscles the way dinosaurs actually wore them, then their accuracy approaches that of, say, the musculature page

Patrick O'Brien painted a reenactment of a battle 80 million years ago between a protoceratops (left) and a velociraptor for the American Museum of Natural History. His rendering is based on up-to-date scientific analysis of fossilized skeletons found in 1971 in Mongolia (inset).





Velociraptor has been represented in three distinctly different artistic guises in recent years. In the 1993 film *Jurassic Park*, the dinosaur was portrayed as a menacing human-sized lizard (inset right). In the recent film *Dinosaur*, it was a sleeker, snakelike road runner (inset left). At the American Museum of Natural History (above), artists working closely with a team of paleontologists rendered *Velociraptor* as a wingless creature with feathers.



in a human anatomy book: not a bad indication of what we look like on the outside, but still missing breasts, ears, noses, pot bellies, and all the other soft-tissue structures that define a creature's shape but make no large marks on the bone.

Brougham respects these limitations. A thoughtful 30-year-old with dexterous artist hands that he doesn't use when he's talking, Brougham mentions elephant trunks and ears, tapir snouts, and toucans as examples of creatures whose appearance one could never guess from their skeletons alone. "A toucan is preposterous," he says. Its head seems too big to hold up and "it's too extreme to be true." Still, Brougham believes that reminders of nature's whimsy do not give him license to speculate as many illustrators have done, putting, for example, proboscises or caruncles on a variety of dinosaur body parts. If Brougham doesn't have good information on soft tissues, he won't add any—no hump on the protoceratops's back,

nor droopy wattles under its chin, nor a peacock frill about its crest, even though all are as likely as the trunk on an elephant.

Brougham covered his protoceratops model with an ochre skin embossed with a scaly pattern suggested by fossilized skin impressions. What dinosaur skins actually looked like is one of the least-known elements of reconstruction. Brougham had to guess how the scales might have differed over the various parts of the body. He chose ochre as a neutral tone that might have blended well with the arid sands of the area, subtly camouflaging the creature from the eyes of a velociraptor. Most dinosaur colorations in recent years—and every year brings a wider range of patterns and pigments—are based on guesses about the landscape the creature lived in and its need for camouflage. By necessity, this reasoning makes unscientific assumptions about the ability of dinosaur eyes to distinguish colors and shapes. Eyes are a soft tissue that we will likely never have

direct evidence for, paleontologists say. We do not know what dinosaurs saw, or if they saw in color, so we cannot know how they evolved to hide from one another.

We also can't know what the eyes themselves looked like, although they are major contributors to the appearance of a dinosaur face presented to the public. The slit pupils of reptiles and the round pupils of birds are good guesses, but artists have tended to go with slits only when they want the dinosaur to look mean. Brougham's protoceratops has nondescript beads with round pupils.

The rest of the face of Brougham's protoceratops is the same shape as the fossil skull. There are no extra flourishes, folds, or fringes except around the mouth, where he pulled the flesh over the sides of the jaw to make cowlike cheeks. Cheeks "look right," he says, but there's no conclusive evidence for them. The Disney dinosaurs also have cheeks, as well as fringes that look like eyebrows and lips for speaking English. Brougham put the

We do not know what dinosaurs saw, or if they saw in color, so we cannot guess how they evolved to hide from one another

nostrils on his protoceratops far forward, near its beak, following the example of most living creatures. Think of alligators, lizards, dogs, and donkeys: The nostrils go as close to the mouth as the nasal cavity will allow. Vertebrates like to lead with their noses. Disney's dinosaurs follow a different example, quite popular in dinosaur art. Their nostrils are farther back on the snout, halfway between the eyes and the mouth.

The velociraptor that stalks the protoceratops in the diorama is also based on a series of educated guesses about skeletal and soft-tissue structure, with one added consideration: This velociraptor has feathers. A multicolored frill graces its pate, and the rest of its body is covered in a fluffy sheath of unusual feathers that dinosaur artists have come to call *dinofuzz*—definitely not fur, but not quite feathers either. The feathers were Norell's idea. They're not required by direct fossil evidence, but there is a debatable set of quill-like impressions around some fossil finds. To Norell, it's important to read these as feathers all over the body because the major thrust of his work as a scientist is to show that dinosaurs are direct ancestors of modern birds. The small fossils that line the walls of the Fighting Dinosaurs exhibit have helped him further establish an evolutionary lineage from *Tyrannosaurus rex* and *Velociraptor* to the emu, the tit, and the vulture. But he cannot prove these relationships. Very little in paleontology is subject to direct proof because we cannot resurrect these creatures. Nevertheless, it is a legitimate working hypothesis, and ensconcing a hypothesis in artistic reconstruction is common practice in scientist-artist collaborations.

So. The bones are evidence that's interpretable. The muscles are guided guesswork. Everything else—soft tissues, skin, folds, frills, cheeks, lips, eyes, nostrils, pattern, color, covering—is artistic license, or, in the case of Norell's feathers, scientific license. How far off could the dinosaur renderings be?

The most conservative answer, which many scientists give, is that we just don't know. Paleontology is the study of fossils; fossils are limited in the information they provide, so

we will always run the risk of drawing a titanic hamster instead of an elephant, and we'll never know if we're doing it. Artists give a curiously different answer. In a sense, they know better than the scientists how far off they might be because they are the ones who must constantly do the guesswork. Many artists agree we'll never know whether a particular drawing accurately represents a creature that's been dead for 80 million years, but they also say it is possible to get a sense of how far off dinosaur art could be by exposing the process of layered guesswork. Hallett puts it this way: If he took a set of scientific evidence about a dinosaur and allowed himself to explore all the possible muscle placements, soft-tissue structures, facial variations and skin tones and patterns and folds and frills, he says he could draw a series of

solutions and "come up with very different-looking dinosaurs." To scientists, of course, they'd all be the same, based on the same evidence. But to museum goers, they'd be different creatures. The Society for Vertebrate Paleontology's Scott Sampson thinks such a varied lineup would be a great way for the science to peer through the art, because the only constant across the range of pictures would be hard facts: "Don't just illustrate [a few options] with a given set of evidence, but do the whole range. Vary everything and get 17 different things. It underscores our ignorance about these animals."

Museums and moviemakers seem not likely to offer that approach soon. You can't have a movie dinosaur looking entirely different from one scene to the next. The art is supposed to convince the viewer of the image, not of the science behind it. "I want to suspend the disbelief as much as I can," says Michael Skrepnick, a Canadian paleo-artist who has done dinosaur illustrations for *National Geographic* and various museums. "I want you to believe in the animals you're looking at. I want you to think they're real." It is also uncommon for differing interpretations to crop up among illustrators. Because illustrators know how much hard work

FLIGHTS OF SCIENTIFIC FANCY

PEOPLE WHO WERE MORE THAN 20 YEARS OLD WHEN *JURASSIC PARK* CAME OUT IN 1993 will remember that the zippy, jeep-chasing *Tyrannosaurus rex* wasn't the same creature they'd grown up with. He didn't lumber or drag his tail on the ground, as *T. rex*es did in earlier movies. What we were used to came out of the scientific assumption—which held sway for the better half of this century—that dinosaurs were cold-blooded. There was no proof of cold-bloodedness, but it was the most popular working hypothesis for three generations of paleontologists. That hypothesis was writ large in art. *T. rex* dragged his tail because he was sluggish. *Brontosaurus* (now called *Apatosaurus*) was too massive a creature for a cold-blooded circulation to support on land, so artists depicted him wading through swamps, near crocodilian ceratopsians basking on the shores. In the late 1960s, a scientist named Bob Bakker began to challenge cold-bloodedness. He reinterpreted fossils to look more like warm-blooded bones. Over a decade or two, most paleontologists came to a vague consensus—still considered controversial because no one can prove it—that dinosaurs regulated their own body temperatures. All of a sudden, these huge creatures had to keep warm. So instead of lolling about like lizards in artwork, they careen about like cheetahs. Doug Henderson of Earth History Illustrations in Whitehall, Montana, notes that a scientific hypothesis will not simply enter the artwork as a possibility—as the best scientific guess that it really is. Rather, it takes off like a known truth and is expressed to the extreme. We've gone from the earlier torpor of a swampish lost world to today's art, in which "The level of activity has gotten to where the dinosaurs have got bees up their butts!" says Henderson. These days, the hotly debated notion that birds are descended from dinosaurs is the latest notion to run amok in art, and not just with *Velociraptor* and other creatures that had birdlike skeletons. Even a baby *T. rex* was recently sighted wearing feathers. —W.S.W.

goes into reconstructing a dinosaur for the first time, they respect one another's original interpretations. Once a species is painted or sculpted, later illustrators generally honor the speculations of the original artist.

There is yet another take on dinosaur art, one that comes from a small but growing circle of young paleontologists who say that many of the decisions currently guessed at by artists might someday be based on real evidence from scientists. Larry Witmer, a professor of anatomy at Ohio University's College of Osteopathic Medicine, maintains that scientists can increase the yield of data from the bones they've got. All they have to do is look closer. His idea sounds simple enough: Look hard at the bones of modern animals to study the tiny marks that soft tissues make on bones, and see if such subtle marks can be found on dinosaur fossils as well. This growing field of soft-tissue research is a radical departure for paleontologists, most of whom were trained in geology (fos-

the course of evolution. "Soft tissues evolve, bones respond" is Witmer's working slogan.

In the case of tapirs, Witmer found that their skulls have various characteristics such as nerve passages, blood ducts, and small muscle attachments that are caused by the snoutlike structure, and therefore necessary for the snout's existence. When he searched for these characteristics on *diplodocus* skulls, he found none. His inference that *Diplodocus* did not have a tapirlike snout now has some scientific basis. Witmer did a similar study of the mooselike jaw muscles that some illustrators put on duck-billed dinosaurs and found that duck-bills do not have the hefty bone structure moose need to support such prominent jowls. He understands why the artists put them on in the first place. The big muscles "look great in reconstruction." Most renderings of duck-billed dinosaurs have that same familiar look of *Iguanodon*s—they are great lizards reminiscent of horses. "If you make a duck-billed dinosaur look like a

Larry Witmer (opposite) makes scientific inferences about the soft tissues of dinosaurs based on his comparative analysis of microstructures in dinosaur fossils and the bones of various modern animals, including the white rhino, the manatee (the skull in the scale), and the hooded seal (CAT-scan images). Witmer also studies crocodiles and birds, which are the closest living relatives of *Velociraptor* (skull next to the tray of tools) and *Deinonychus* (in his hands).

Witmer continues to dissect modern animals, looking for tiny, signature bone structures that they might share with fossil dinosaurs. He just obtained "a wonderful huge head of a rhino," which required a bigger freezer in his lab. Many paleontologists have maintained that the horns of ceratopsians were rhinolike, and Witmer can now test that hypothesis. He's on the lookout for crocodiles and birds, too, because they hold the best clues to dinosaur soft tissues. The ideal find for him is a set of soft-tissue marks on the bones of both crocodiles and birds. If he can find those same marks on dinosaur fossils, he has strong evidence that the dinosaur had the same soft tissue. He has already used this technique to establish that dinosaurs had an air sac housed in a skull cavity between the eye socket and the nasal opening. For more than a century, paleontologists kicked around hypotheses as to the cavity's function: It was a muscle, it was a gland for salt. Crocodiles and birds have air sacs in that cavity, and those air sacs leave the same characteristic microscopic marks Witmer found on fossil skulls.

This subcutaneous soft-tissue discovery doesn't dramatically change the outside look of dinosaur art. And Witmer's goal isn't to improve dinosaur art. His purpose is to learn more about questions like: What organs did dinosaurs have and what were they used for? But Witmer's work, and the work of a handful of other young paleontologists who are approaching the soft-tissue questions with scientific methods, may ultimately allow artists to flesh out dinosaurs with more hard data. "Anything that increases the chances of a paleo-artist [rendering] something more accurate would be welcomed with open arms," says Hallett. He says he and his colleagues aren't in this business to make guesses. They want to know the truth.

And what about all the paleontologists who say anyone trying to figure out what dinosaurs really looked like is asking the wrong question? Deep down inside, suspects Hallett, they want to know too. ☒

We often think of bones as a stiff scaffold that everything else hangs on, but anatomists know that soft tissues morph bones as an animal grows

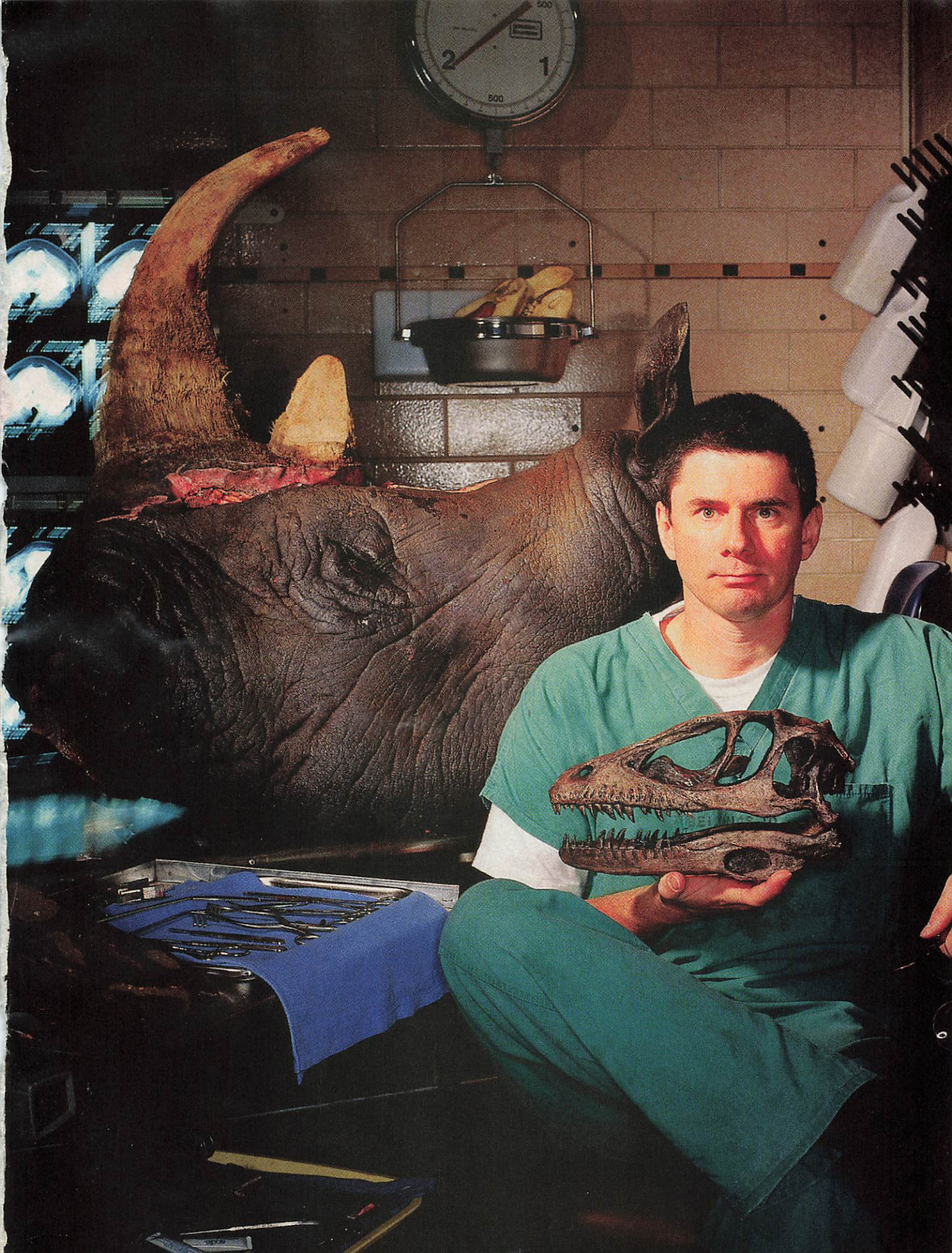
sils are rocks found in rocks). Their soft-tissue analysis of bones has been largely limited to the muscle scars that can be seen with the naked eye. "People thought that soft-tissue stuff was just truly out of reach—that there was no rigorous way to know, so they just let the illustrators do it," Witmer says.

As a full-time teacher of anatomy, Witmer cuts up more animals in a year than most paleontologists do in a lifetime. He is a tall man with young features and a frame that would have no problem flipping over a walrus cadaver on a dissection table. Curious as he is about the relationships between soft tissues and bone, most of his work is delicate, requiring a dental pick, a magnifying glass, and a hefty amount of patience.

When colleagues suggested that the dinosaur *Diplodocus* might have a tapirlike snout, Witmer methodically dissected three tapirs (as many as he could get his hands on) looking for what he calls "osteological correlates" of the snout. We often think of bones as a stiff scaffold that everything else hangs on, but anatomists know that soft tissues actually morph bones as an animal grows, and over

horse, which so many illustrators do, well, it looks right. But we have reconstructed it in modern guise," Witmer says. We live in an era of mammals, so dinosaur art is heavy with mammal flesh that is simply out of place. Dinosaurs are more closely related to snakes than they are to mammals. Moreover, moose and horses are no better guides to what dinosaurs looked like than manatees, humans, or voles.

Commenting on the series of choices illustrators have to make, from muscle reconstruction to soft tissues and facial features, Witmer suggests that any time an artist makes a decision because it "looks right," he risks falling into the mammal trap. Artists could do a better job by stealing soft tissues from crocodiles and birds to flesh out their dinosaurs, he says, and science-minded artists like Hallett, Skrepnick, and Brougham have already begun to do so. Witmer does not expect the approach to satisfy our expectations. "If you go back and do it right, then it'll look totally weird. But it'll be right," he says. "We've missed a lot of their bizarreness by using these false analogues."





DOWNLOADING YOUR BODY



OPERATING IN CYBERSPACE WILL SOON
TAKE THE GUESSWORK OUT OF REAL-TIME SURGERY

BY WILLIAM SPEED WEED PHOTOGRAPH BY MAX AGUILERA-HELLWEG

DR. CHARLES TAYLOR WOULD LOVE TO EXPERIMENT with your arteries. He's a natural-born tinkerer, and the idea of operating on you only once and calling it a day seems less than ambitious to him. He's especially interested if you happen to be one of the millions of Americans who suffer from atherosclerosis: dangerous buildups of arterial plaque that hinder blood flow, causing pain, heart attacks, strokes, and in the worst case, death. Were you to hand over your clogged arteries to Taylor, he'd play vascular surgeon and gleefully perform as many as five, even 10 different surgeries on you. And before long he'd be wanting your

heart, your liver, and your lungs in order to cut them, stitch them, and subject them to all sorts of pharmaceuticals. Ultimately, if his wish comes true, Taylor will have all your body—down to the last molecule—trapped right where he wants it: on his computer.

TAYLOR IS NOT A MEDICAL DOCTOR. HE IS A DOCTOR OF ENGINEERING, but he is also an assistant professor in the departments of surgery and mechanical engineering at Stanford Medical School. He has never cut into a live patient to fix blocked arteries, as his surgical colleagues do every day. Instead, he and his graduate students spend their days perfecting a software program they invented called ASPIRE—Advanced Surgical Planning Interactive Research Environment.

The program gives a vascular surgeon the opportunity to tinker in cyberspace with a patient's arteries, experimenting with different placements for arterial bypasses, different makes of artificial arteries, and a variety of other options to restore blood flow. In virtual reality, doctors are free to follow hunches, even to commit errors, with the luxury of trying again and again until they have explored every option. Then, with the click of a button, ASPIRE can predict which choice will have the best outcome. Right now, by contrast, each vascular surgery is a one-shot experiment performed in real time.

Christopher Zarins, the chief of vascular surgery and a surgeon with decades of experience, describes the current method of choosing the right vascular procedure as "guesswork." If ASPIRE fulfills its promise, Taylor will take that word out of Zarins's vocabulary—and profoundly change the practice of medicine.

IN 1993, CHARLES TAYLOR WAS STILL A PH.D. CANDIDATE IN mechanical engineering at Stanford, spending his time developing computer software to test how fluids flow around different materials and shapes. His studies were funded by the U.S. Air Force, in the hope that his work would lead to more efficient airplane wings. That winter he attended a lecture delivered by Zarins on fluid dynamics and plaque formation because he was curious to see if the surgeon's research would echo his own work.

Most vascular surgeons concentrate on the repair of blood vessels, but Zarins is interested in the engineering principles underlying diseased systems. That day he talked about shear stress, turbulence, and pressure gradients, a vocabulary familiar to Taylor. As Taylor listened, he realized—in what he calls a personal epiphany—that the blood flow of the human vascular system was reducible to the equations of mechanical engineering and was, therefore, a legitimate subject for computer-aided design. He decided in that moment to make a virtual model of an individual's arteries that would allow surgeons to try out alternative operations before cutting.

Zarins immediately grasped Taylor's vision and, along with Thomas Hughes of the department of mechanical engineering, offered to support his research. So Taylor abandoned airplanes and started adapting his computer modeling tools to build virtual vascular systems. "Not hard to do at all," he says. "Fluid systems are fluid systems, be they air over a wing or blood through a vessel. The coefficients are different, but the equations are essentially the same."

Doctors already use computers for imaging the insides of patients and for guiding procedures in real time. Programs exist that train student surgeons to operate on so-called average patients. But Taylor's is the first tool that uses actual physiological data from an individual patient to predict the success or failure of a procedure on that patient. The tools that Zarins uses today to plan a surgery—pencil and paper—look primitive to engineers. Zarins can sketch out his various options: angioplasty or bypass grafts? Real or factory-made



The software program ASPIRE predicts the improvement in blood flow yielded by different vascular surgical options, giving surgeons new knowledge before they cut into the body. [1] This arterial model shows the clinical problem. The abdominal aorta branches into the two femoral arteries that supply blood to the legs, and the gray area at the top represents a dangerous blockage. [The blockage below is not a concern because it is causing no symptoms.] [2] New white branches indicate a bifurcated bypass graft. Here the graft is made to the side of the aorta so that blood flow will be split between the aorta and the graft vessels. This choice yields maximum blood flow overall but creates the potential for a clot because blood will travel slowly through the aorta. [3] The surgeon bypasses the aorta entirely with an end-to-end graft, sewing shut the lower portion of the aorta. This procedure yields less blood flow but carries less risk of clotting. [4] For a patient who cannot withstand the open-abdomen procedure required for the previous two choices, a less invasive femoral-to-femoral graft may be the safer option.

arteries? What shape tubing? Which points of insertion? But he cannot predict how any of these options will serve a specific patient post-operatively. "The way we are doing vascular surgery is by building it and seeing if it flies," Zarins says.

Taylor, in fact, sees his mission as strikingly similar to how aeronautical engineers design aircraft: "They build a model of the plane on a computer, digitizing its every component and quality. Then they fly it through cyberspace, subjecting it to various wind speeds and flight patterns, and calculate its performance. They are so good at modeling the plane, the atmosphere, and the flight contingencies that they can predict the success of their design and modify it to ensure perfection before they ever build it."

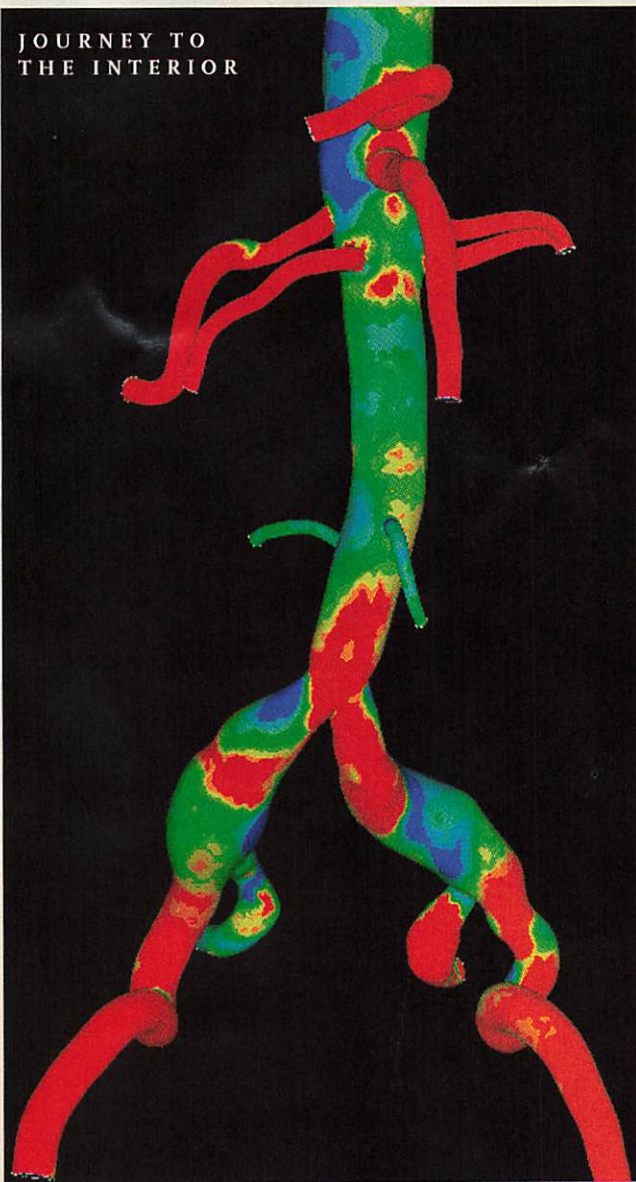
Doctors who have worked with ASPIRE are excited. "The immense variability of human disease makes things unpredictable for us," says Dr. Frank Veith, the chief of vascular surgery at Montefiore Medical Center and Albert Einstein College of Medicine in New York. "I can

operate on 100 people with a similar problem, but with the 101st, I still can't be sure what will happen." A man at the top of his profession, Veith says he is still "constantly worried about making the wrong decision" when he chooses which surgery to perform.

ASPIRE aims to translate every characteristic of a patient's vascular system into computer numbers and thus create a cyber rendering of reality. It uses every bit of vascular data available from the patient: the three-dimensional geometry of his arterial system, his

This computer image of the abdominal aorta of a 67-year-old research patient models the pressure of blood flow on the interior of the vessel walls, represented by a range of colors from red to blue, red indicating the greatest blood flow and blue the least. Doctors monitor areas of blue because they are sites at which coronary artery disease is most likely to develop. This volunteer was chosen as a healthy subject, but the value of ASPIRE's ability to describe individual anatomy was demonstrated by this graphic, which revealed a potentially serious problem: The bulges just below the bifurcation of the aorta are aneurysms, and the patient may one day be treated as a result of his participation in this pilot study.

JOURNEY TO THE INTERIOR



CHARLES TAYLOR

blood pressure, viscosity, and heart rate. It then feeds them into standard equations drawn from fluid dynamics that mathematically encode blood flow and resistance at each point in the patient's system.

Armed with this information, ASPIRE generates on-screen a three-dimensional graphic that the surgeon can rotate and assess from any angle. The graphic shows the surgeon how blood is flowing through the vessels, where the flow is good and where it is obstructed. From a tool bar the surgeon can grab any instrument or device he could possibly want: bypasses and shunts of different shapes and sizes and angioplasty balloons for clearing out plaque. He can manipulate the tools using the computer's mouse as a scalpel. After performing an operation, the surgeon can reset the program and the baseline so that the same set of clogged arteries pop up on the screen again, ready for a second, different operation. Having performed as many operations as he wishes (Taylor speculates that four will be average), the surgeon clicks a button, and the program begins analyzing the new arterial architecture each surgery would give rise to, calculating how much blood would flow through the repaired vessels.

FOR TAYLOR, CAPTURING THE DYNAMICS OF THE VASCULAR SYSTEM

is just the first step. The system of blood vessels is essentially plumbing, and the amount of data one needs from a patient to replicate that system in cyberspace—about one gigabyte—is relatively small in comparison with the incalculable millions of gigabytes Taylor says will be necessary to reproduce the human body. However, even Taylor's modeling of the vascular system makes great demands on a computer. To run ASPIRE and model a single set of surgical choices now takes 24 hours. Taylor is waiting for computer power to double a few more times, so that results can be generated in about an hour, before he makes it available to surgeons.

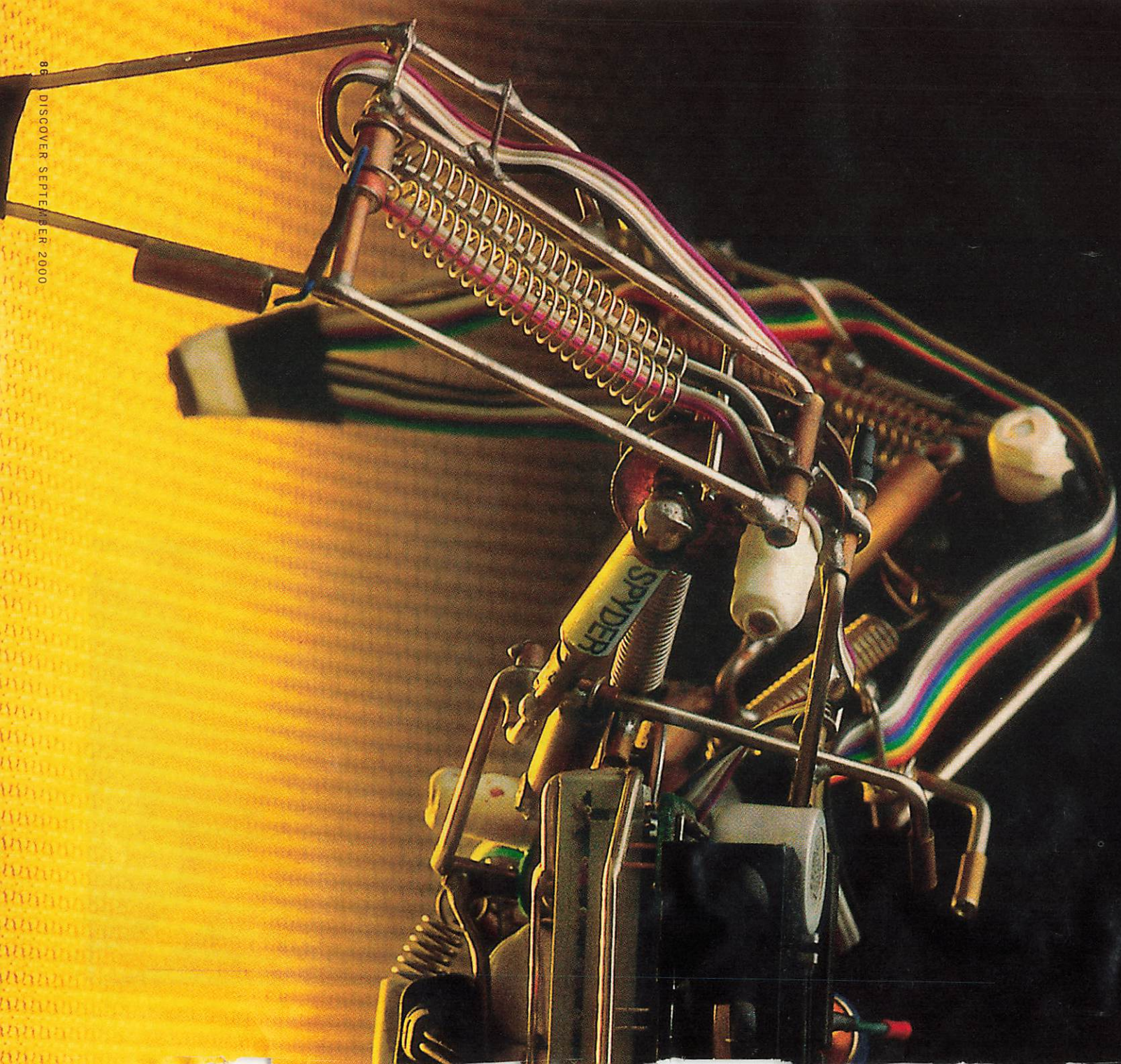
It is also going to take time to win a difficult philosophical battle in the medical community. Not everyone is easily convinced that human beings can be modeled like airplanes. If we're organic, how can we possibly be digitized? Aren't we ineffably complex? To an engineer, nothing is ineffable in numbers. "It all comes down to our mathematical representation of the world," says Taylor. "Computers can solve the problems if we pose them properly." But if ASPIRE's problems are ill-posed—if Taylor's equations are inexact, if his program lacks a line of code—then his revolution might well founder. He knows it must be flawless.

So he hones his equations and edits his code. So far, using ASPIRE on pigs, Taylor has searched for discrepancies between the virtual version and what actually happens postop to the pig. He's close, he says. So close that he's ready to start shadowing human patients early next year, comparing the program's recommendations with outcomes of actual surgeries in order to see if its predictions are accurate. Taylor hopes he is no more than five years away from perfecting ASPIRE.

Once he has mastered arteries, Taylor plans to tackle hearts and then move upward in complexity. "It's only a matter of computational power—and knowing what the data set is for the model," he says. "If the vascular surgery model proves effective, we could make patient-specific models of the cardiovascular system, pulmonary system, even gastrointestinal. Chemotherapies and tumors. Ultimately, pharmaceuticals and cells. It's a hundred-year problem," he says. "A full human is the most complex system anyone might seek to describe, but we will construct a digital human."

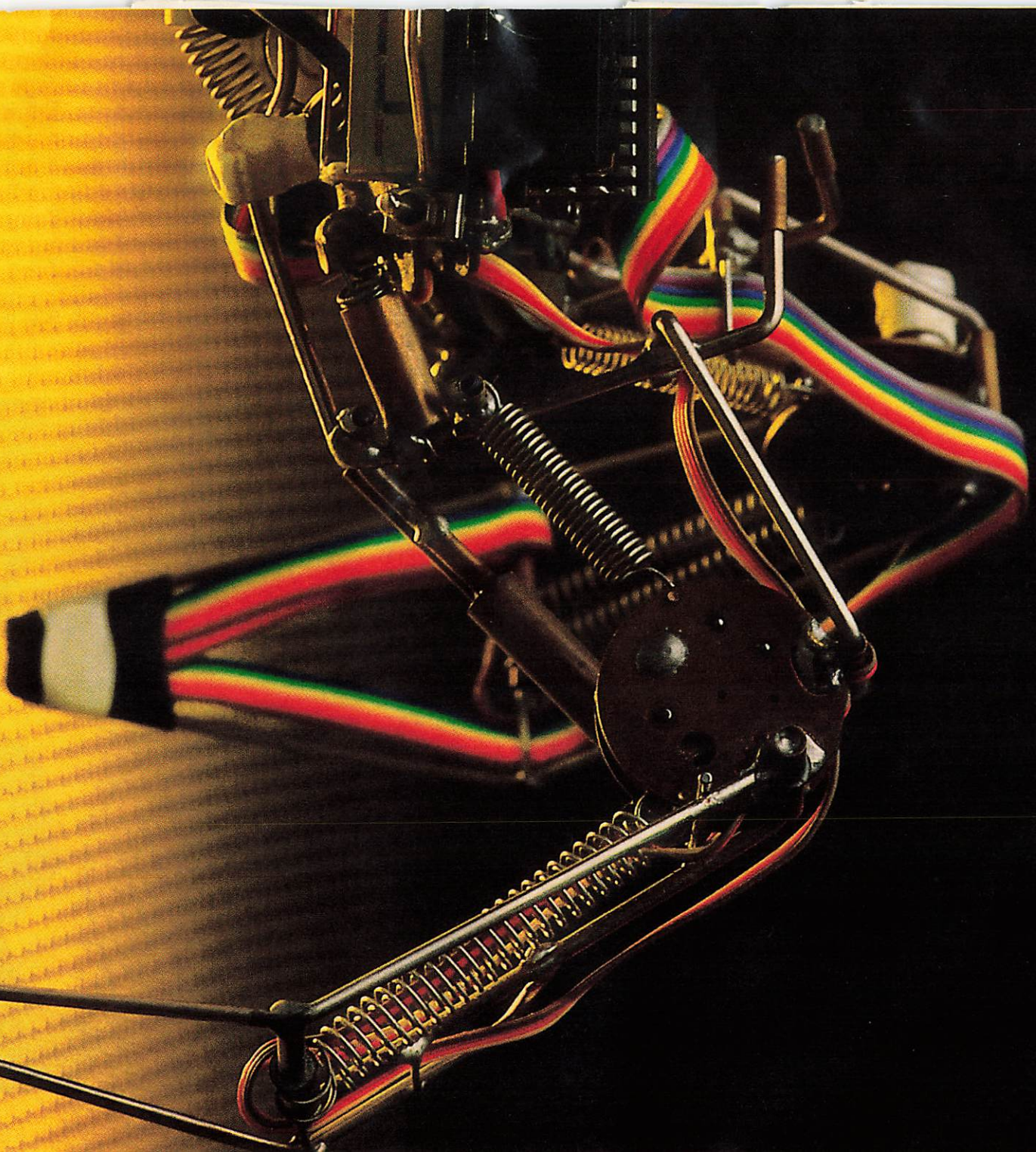
If it works, it might be the ultimate reductionist achievement: not just a vascular system, a heart, an intestinal tract, liver, bones, muscles, or a brain, but all of them together, their relationships accounted for, a cyber avatar—you, on disk. ☒

DIY



CAN MAN MIMIC ORGANIC LIFE-FORMS WITH MACHINERY? TAKE A LOOK ...

BY PETER MENZEL AND FAITH D'ALUISIO • PHOTOGRAPHY BY PETER MENZEL



Mark II's Spider walks without any software. Its "nervous network" seeks minimum energy, moving its legs almost randomly until it succeeds. Length: 9.5 in. Weight: 1.6 lb. Component cost: 50 cents in transistors, the rest from junked tape decks, cameras, and VCRs.

THIS IS MY MAIN LAB AREA," Mark Tilden says about the dining room in his home. On a dusty glass-topped table are several multi-legged, flat-bodied robot creatures the size of television remote controls. They have whimsical names like Ogre, Snakebot, Walkman, and Strider, and scientific designations like CTD 1.4, VBUG 3.3, and GPIM 2.4. ¶ On a workbench in an upstairs bedroom, more small robots are under development, scattered amid snippets of wire, solder, and sheets of specially designed, wafer-thin circuit boards. Still more are tucked into cases that shuttle back and forth among exhibitions and museums. All the machines are small and all are analog-controlled—there's not a single digital processor among them. ¶ Officially, Mark Tilden is a robotics physicist at Los Alamos National Laboratory in New Mexico, but he is principally interested in what he calls biomorphic robots. They are made from transistors, motors, sensors, and anything else he cares to throw in, with many parts salvaged from cast-off cameras and video-cassette recorders. He endows his machines with what he calls "nervous networks," which function much like the neurons in animal nervous systems.

Unlike conventional robots, which are usually based on digital technology, Tilden's nervous-network machines are based on analog technology using continuously changing waves, rather than ones and zeroes. Instead of writing elaborate programs to make his robots walk, he designs circuits that automatically seek a desired state. Motion is usually the result.

When his robots encounter obstacles, they frantically try to get back on track, sending out a blizzard of almost random impulses until they manage to scramble past the obstruction. The results are startling: Tilden's devices can skitter over almost any terrain.

Given the contrast between the fluid motions of his inexpensive machines and the stiff, clumsy behavior of many more-costly robots, it is little wonder that the bombastic Tilden enjoys the role of vocal skeptic about the digital world and professes enjoyment of the drub-

bing he sometimes gets. "I don't use computers except to comb the nits out of my beard," he says.

That's an exaggeration. Tilden returns e-mail with unnerving speed. At the same time, he's serious about advocating analog. "As soon as a device has to interact with complex worlds—like a forest, or a field, or a human—then digital hits the complexity barrier, where a small behavioral improvement can cost thousands of man-hours. We're already seeing this with computers, and they just have to sit on a desk. If laptops did have to move and work in the real world, the complexity required would continually demand precise, predictive updates. This just isn't easy to do in the language of digital logic. They're too fragile to take risks as living things do.

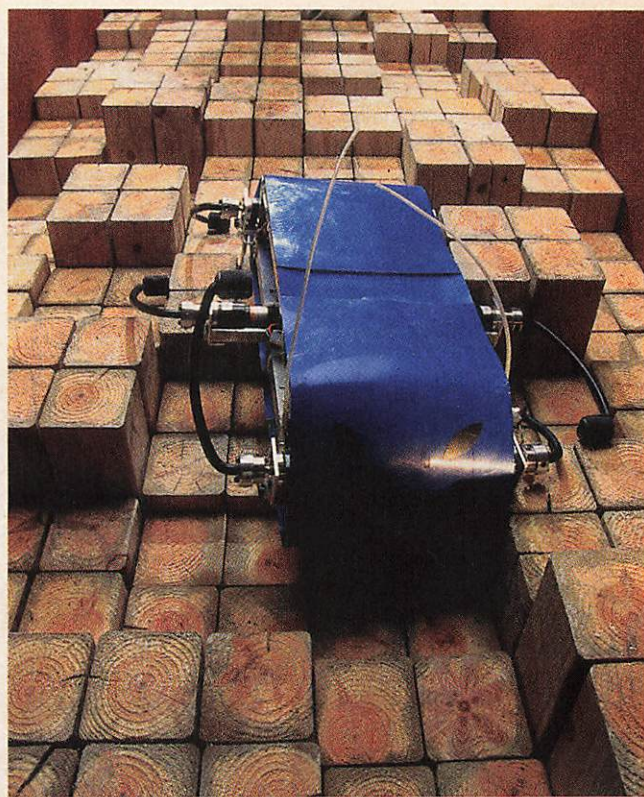
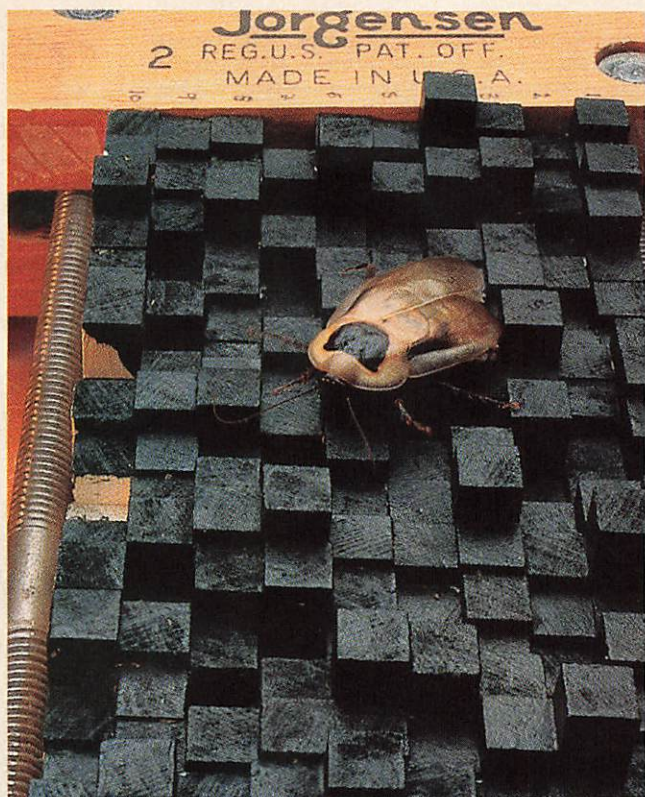
"Even worse, it may not be necessary. Nature uses analog answers, but we can't build those. I believe there's another way, ideal for robots themselves. That's why I'm exploring analog devices to see if there might be other solutions to making a machine think it's alive."

Tilden is always wary of what he calls "Wizard of Oz" demonstrations: "Pay no attention to that graduate student behind the curtain—I am the great and powerful roboticist of Oz." If you see a machine with a whacking great big cable or antenna coming off it going to a supercomputer run by various grad students, then you are looking at a Wizard of Oz demonstration. If it repeats a behavior pattern, then you've got a puppeteer on tape. There are over 10,000 special-effects masters on the planet right now. But if you count the number of people who are really researching robots, who are trying to go beyond fiction, the total is small compared to the people who are making Jim Henson machines that run [using] human control."

And that is partly because people don't accept robots easily. "We built de-mining robots, grass cutters. We built everything," Tilden says. "Self-contained, solar-powered, automatic devices that don't require any programming and in many cases don't even require batteries. You just have to put them in the dishwasher every now and then. But they didn't sell! They crawled off the shelves when we

On the glass-topped table in his home where he builds most of his robots, Mark Tilden shines a flashlight on the head of Nito 1.0. When complete, the machine should interact in a simianlike fashion. Nito's head, mounted on a small circular test pedestal, has sensors that respond to light.





tried to market them, no pun intended. The fact is, people have media-enforced expectations of robots. They demand robot characters.

"Take a look at all the major artificial characters that you think you know. You'll find out that they're all human characterizations: Robby the Robot from *Forbidden Planet*, Commander Data [from *Star Trek, the Next Generation*]. The fact is, people want a character that essentially is a metal embodiment of a human personality. You have to start building things that fall in with people's expectations—that a robot is a faultless Commander Data, wearing an apron, who pushes a broom and fetches you a beer. It is not some sort of machine that roams around the hall or cleans under your couch, even if that's what the robots are best at.

"In 1982 I tried to build a digital home robot butler and found that it looks really nice on *The Jetsons*, but it's the last thing you want in your environment. Why? How can you program a robot not to eat the book that you were reading last night? Or to leave your loose laundry alone?

"The funniest thing was when I walked into the kitchen and there's my robot sucking up the cat kibble, and the cat is looking at me as if to say, 'Get this thing out of my face!' What was awful was finding out that even in a single bachelor apartment I could not come up with all of the sub-routines necessary to make this thing useful. Also, I kept tripping over the damn thing.

"Trip over your dog or cat in the night and they're soft, they'll heal. You trip over your robot, you swear like a trooper, and you're in for a \$5,000 repair the next day. Imagine if your laptop decided to walk around your house. My conclusion is that having a robot to make your bed would be like getting a Sherman tank to mow your lawn."



A roach [above left] doesn't avoid bumping into things but just keeps thrashing forward. Its brain is not even aware of its feet, so Martin Buehler and Daniel Koditschek made RHex the same. It moves so fast that its legs are hard to see. Length: 20.9 in. Weight: 15.4 lb. Component cost: \$10,000.

ROAD RHEX

With its decal eyes, fake plastic antennae, and mouse-pad feet, RHex 0 isn't much to look at. But the conceptual underpinnings of this six-legged robot are a potential blockbuster for robotics.

In 1998, Martin Buehler, a McGill University roboticist, was captivated by biologist Robert J. Full's video of cockroaches navigating a bumpy surface. In ultra-slow-motion, Full revealed that the creatures were constantly stumbling and bumping into obstructions. Nonetheless, they continued to run swiftly, suffering little loss in performance.

With Full's encouragement, Buehler decided to borrow the principles of cockroach design to create a walking robot. According to his longtime mentor, Dan Koditschek of the University of Michigan, Buehler roughed out the design by sticking "paper clips into an eraser—a conceptual eraser—and said, 'We can build this.'" RHex the roach-bot is now a full-blown collaboration among Buehler, Koditschek, Full, and Michigan graduate student Uluç Saranlı.

Buehler cautions that RHex is just an early prototype. But even in its crude, unfinished state, the squat-bodied, autonomous machine is wicked fast. Set in motion, RHex moves so quickly that its legs are hard to see, much like the cockroach's legs in Full's video.

What's next for RHex? Maybe a RHex 1 that hops and runs and does more eye-popping demos. Buehler says: "RHex 2 will have articulated legs, with just the knee, to be able to get better mobility. Right now the mobility is somewhat limited—it can't go under cars, because it has to rotate its legs around. After that, RHex 3 would have even more actuation per leg—with a hip and a knee—so it would look more like a cockroach."

Excerpted from *Robo sapiens: Evolution of a New Species*, by Peter Menzel and Faith D'Aluisio. A Material World Book. Copyright 2000 Peter Menzel and Faith D'Aluisio. Published by the M.I.T. Press, fall 2000.

CLAW AND ORDER

Joseph Ayers, head of Northeastern University's Marine Research Laboratory, has been researching lobster locomotion for more than 20 years. Based on Ayers's studies, staff researcher Jan Witting is building a robotic lobster that will capture the behavior of a real lobster.

Unlike many biomimetics researchers, Ayers is trying to come close to duplicating the principles of a living creature mechanically. On the other hand, the project has enough potential that it is funded by the Defense Advance Research Projects Agency. Although its eight legs are in place and working, the battery-operated machine shown below lacks the tail and claws that will stabilize it underwater. Real lobsters are buoyant and almost float along the ocean floor, with their claws and tail extended in a triangular shape that maximizes their stability. Ayers has since added stabilizers at the front and rear.

Some biologists who work with roboticists want to reproduce accurately every part of an animal, but Ayers says: "To me, the big picture is the major organizational or governing rules by which you operate the thing. Others are very focused on their robot behaving exactly the same way as the animal. I want to say which details are important and focus on the governing principles."

What's important in the lobsters, he says, is "their ability to go and find something on the bottom of the ocean. If they want to go out and find trap bait, they can get through anything. It's that kind of performance capability we want to capture. And energetically, they are very efficient."

Ultimately, he says, "the goal is to build robots that are autonomous. That's the Holy Grail as far as I'm concerned—autonomy."



Joseph Ayers's lobster robot, called BUR 001, is designed to find mines underwater. Lobsters don't need to see to find prey, and BUR 001 will find targets the same way—by feeling its way along. A tail and claws will stabilize it. Length: 24 in. Weight: 6.4 lb. Component cost: Roughly \$1,000.

iRobot's Ariel moves sideways like the crab it was patterned on. It can walk with its body upside down if it's flipped over in the waves while it searches for mines. Its sensors are stuck out at each end to avoid interference from the legs' motors. Length: 45.3 in. Weight: 24.2 lb. Component cost: \$50,000.



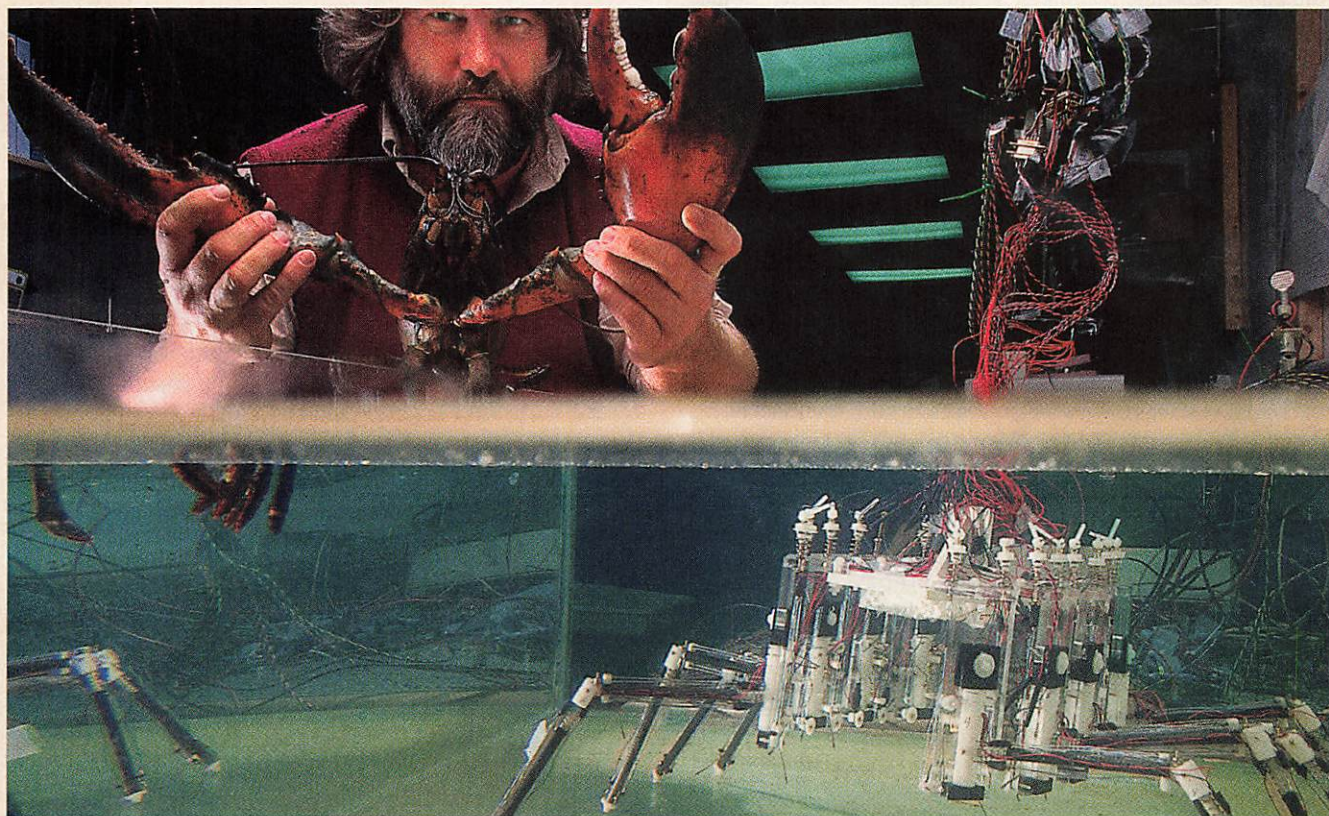
CRAB DIP

Sidling along the edge of a reservoir outside Boston, Ariel the crab-robot moves with a slow, steady sideways gait. It is designed to scuttle from the shore through the surf to search for mines on the ocean floor. Ariel was funded by the Defense Advanced Research Projects Agency and built by iRobot, a company founded by Massachusetts Institute of Technology robot guru Rodney Brooks.

Inspired by research on crabs at Robert Full's lab at Berkeley, Ariel takes advantage of the animal's stability—and improves on it. Unlike real crabs, which must struggle to right themselves if a wave flips them on their backs, the robot simply reorients itself and keeps walking with its body upside down. Housed in a waterproof cavity, Ariel's electronics feature self-adaptable software—if one of the six legs fails, the programming realizes it and adjusts to a five-legged gait. Fleets of these bottom crawlers communicating with one another could thoroughly sweep an area.

The machine has a compass and a tilt-and-roll sensor sticking out at each end, far away from interference caused by the magnets in Ariel's motors. "For dealing with real-world situations, coming up from the hardware and sensors is very much how animals do it," says Ed Williams, the technician in charge of Ariel. "By having a very small controller and really bringing [in] that mindset, we can do things that are fairly successful and fairly tight, in cheap packages."

Williams supervises Ariel's excursions with great anxiety—the machine still gets stuck when it encounters big rocks. "Robots can't do much now," he says, "but airplanes couldn't do much in 1910."







A gecko and iRobot's Mecho-Gecko cling side by side to an aquarium wall. Mecho-Gecko slaps its feet down the same way as its biological counterpart. Its successors may have the hairy feet that let geckos stick. Length: 4.5 in. Weight: 0.3 lb. Component cost: \$600.



ROBO-GECKO

THE GECKO HAS A DEATH GRIP ON MY FINGER. IT HAS latched on flat-footed, tugging my hand every time its keeper pulls it backward. It feels as if the lizard's splayed toes have melded with my skin.

Robert Full, a biologist at the University of California at Berkeley, stays safely out of bite range while he explains why my finger has suddenly become part of a gecko. Full's lab, working with teams at Stanford University, Lewis and Clark College in Oregon, and iRobot in Massachusetts, is trying to figure out the secrets of the gecko's grip so that engineers can duplicate them. Two gecko-inspired robots they have already built can zoom up glass windows using some of the lizard's fancy footwork.

Lining the undersides of a gecko's toes are gill-like flaps covered with branching hairs, which are capped by roughly a billion microscopic spatula-shaped tips. They do not work like Velcro, glue, suction cups, or static-cling socks. Full and his colleagues believe that those minuscule spatulas come into such intimate contact with what the gecko walks on that the molecules of the two bond together. "It's just like hydrogen bonds to oxygen. We're talking about electron clouds and that sort of stuff," Full says. And those bonds are strong.

out of two robots built by iRobot. The Mecho-Gecko has balls of pressure-sensitive adhesive that roll on like gecko toes. Its successor, the Bull-Gecko, runs on adhesive-covered tank treads that peel up as well. "The peeling means you don't need nearly as much *oomph* to lift off," explains Polly Pook, iRobot's director of research. The robots also have a geckolike tail to stop them from flipping backward as they defy gravity. The company has built leg prototypes for the next generation, a six-legged Hexagecko, which would add a set of cockroachlike claws to dig into softer terrain.

Mobile robots, especially climbers that use sticking mechanisms such as suction cups, have been notoriously plodding and cumbersome. They've had to constantly monitor their position and grasp to prevent a fall, which also meant they were power-hungry. Since the robo-geckos don't spend much energy keeping their footing, they don't need a big battery or a motor that creates a lot of torque. They may not need to plan their steps, either. "Geckos move with reckless abandon, not careful control," says Kellar Autumn, who heads the group at Lewis and Clark College. At full tilt, the lizard's legs deal with obstructions faster than its neurons could command them to. Its legs act like springs, responding automatically the second they hit

"THE ROBOTS' PERFORMANCE WILL BE EQUAL TO OR BETTER THAN THAT OF AN ANIMAL RUNNING AROUND. WE ARE ON THE VERGE OF A REVOLUTION OF SOMETHING WE CAN'T IMAGINE"

"If all the hairs attached at their maximum level," he says, "you could hang a basket of 100 apples off a single foot."

But a gecko can whiz up a wall at three feet per second, so it needs to make and break these bonds quickly. Full found that the hairs are particular about when they're sticky. A gecko rolls its toes down as it plants its feet, looking somewhat like the unfurling of an inflatable party favor. This presses its spatula pads into the wall and drags them backward ever so slightly, speedily ensuring a good seal with the surface. "If the geckos don't do that, then the hairs are almost worthless. If you just touch them, you get nothing, the same as a regular hair," says Full. "We couldn't get the hairs to do anything until we figured it out." The gecko on my hand has that down pat; no amount of yanking makes it come free.

If its feet attach so firmly, how does a gecko let go? When Full ran them up a vertical measuring plate, he found that the animals use no discernible force as they pull away for their next steps. In fact, a gecko uses a surprisingly small amount of energy to climb. Its talented toes are again behind the mystery: They curl upward as they lift off. "It's the same way you take tape off a wall," Full says. "You peel it, so all you have to do is break the bonds at the edge rather than all of them at once." If the gecko then bends its foot hairs above a 30-degree angle, its feet will completely pop off the surface they're bonding to. Full's lizard handler tilts the animal sharply; abruptly my finger is no longer a reptilian extension.

Simply walking the way the geckos walk has made champion climbers

a surface, which is a good method for brainless robots to follow.

Once they get hairy feet, the robots could go even farther. "The gecko's feet aren't ruined by repeated use. They are self-cleaning and they actually work in a vacuum or underwater," says Autumn. The team is now starting to duplicate these features in a dry adhesive, which will work like gecko toes. They have already created a large-scale mock-up of the adhesive. It wouldn't take paint off when it's removed. It could keep car tires stuck to roads, bring together tiny computer components for assembly, or hold slick body parts in place during nanosurgery. And it would let the robots go anywhere.

"The trick is, once you can climb, you can go over or down anything, not just up a flat vertical surface," says Pook. "If you get to a ravine or a boulder, you're not stymied by it." Pook imagines such robots cleaning house. "They could wash windows, find dust bunnies, clean your floors, the cracks and crevices, and the tops of your picture frames," she says. Further afield, they could inspect boats, piers, or bridges, or become permanent maintenance 'droids for satellites. "I would like to see the next generation of Mars rover have legs and gecko feet," Autumn says. Full is optimistic that this will all happen very soon. "Now it's a whole new ball game; the robots' performance will be equal to or better than that of an animal running around. We'll have the gut feeling that they are animals," he says. "I thought it would be 30 years, but that was way off; it may be 10. We are on the verge of a revolution of something we can't imagine."

—Fenella Saunders

Let's Hear It for the Creepy Crawlies

Forget pandas. Amphibians are the star attraction in Detroit

BY SUZANNE B. KAPLAN

2005

"CELEBRITY SELLS" IS JUST AS MUCH of a truism at zoos as it is at movie theaters. In order to draw crowds and swell coffers, zoos typically give giant pandas, polar bears, tigers, gorillas, and other celebrity creatures the starring roles and cast the lowly, more common critters in minor parts. The approach may be lucrative, but Ron Kagan, director of the Detroit Zoological Institute, believes it gives a skewed view of the animal kingdom. "The real story is not in the big cuddlies—it's in the creepy crawlies," Kagan says. "We

have a responsibility to market what's important to nature."

Creepy crawlies are the marquee attraction at the Detroit Zoo's brand new National Amphibian Conservation Center, a \$6.1 million, 12,000-square-foot facility that highlights the critical ecological role played by frogs and their cousins—toads, newts, salamanders, and the little-known wormlike caecilians. Amphibians live both on land and in water and are exquisitely sensitive to changes in their habitats. As such they are living barometers

of the health of the environment and an early warning system of potential threats to humans. Scientists have noted an alarming drop in amphibian numbers, but no one knows exactly why. Among the theories: chemical pollution, parasitic infections, and increased ultraviolet radiation through ozone holes in the atmosphere.

Located on an island wetland, the amphibian center is housed in a pavilion graced with a sculptured frog trio squirting water at a mechanical fly. Visitors step inside to find a spongy floor in an entryway filled with cool, moist air. Croaks, buzzes, and *ribbits* emanate from a succession of galleries featuring an astonishing array of amphibians, including Puerto Rican crested toads, South American burrowing caecilians, and Japanese giant salamanders that can weigh 88 pounds and reach four feet in length. A glassed-in pond allows visitors to glimpse amphibian life above and below the waterline of a Michigan wetland, while an ersatz cave thrills children with dripping stalactites and real salamanders. Penetrating farther, visitors enter an immersion gallery that mimics a Peruvian Amazon rain forest, complete with bromeliads, dracaena, tropical figs,

THE CHACOAN MONKEY FROG, WHICH LIVES IN A SUNNY, ARID REGION IN PARAGUAY AND ARGENTINA, SECRETES A WAXY SUBSTANCE FROM ITS SKIN THAT SEALS IN MOISTURE.





and strawberry guavas, and free-roaming smokey jungle frogs, marine toads, ameiva lizards, swallow tangers, centipedes, millipedes, and giant cockroaches. "Docents tell you to watch your step as you enter the gallery because things literally run across the path in front of you," laughs Kevin Zippel, the center's curator. An occasional drizzle, mist, lightning, and

CAVE-DWELLING SALAMANDERS, LIKE *EURYCEA LUCIFUGA* (LEFT), ARE DWINDLING IN NUMBERS BECAUSE OF HABITAT DESTRUCTION AND DIMINISHING WATER TABLES.

thunder burst add to the experience. "We're competing with television and video games," acknowledges Zippel.

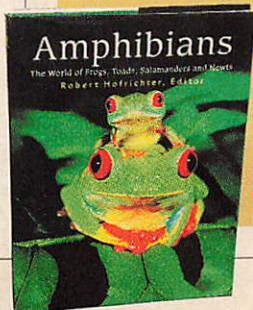
All along the way, exhibits offer engaging instruction. To illustrate the wonders of metamorphosis, a breeding tank features clusters of see-through bullfrog eggs with unhatched tadpoles inside as well as free-swimming tadpoles and mature animals. Other exhibits attest to amphibians' significance in scientific research (they may be a source of potent new antibiotics) and popular culture (the Chinese see a "toad in the moon," the French cook up frogs' legs, and Americans adore Kermit). By the time visitors leave the center, any doubts about amphibians' place on the planet—or in zoos—should have vanished.

AMPHIBIANS: THE WORLD OF FROGS, TOADS, SALAMANDERS AND NEWTS

**Edited by Robert Hoffrichter
Firefly Books, \$49.95.**

This 264-page tome is that rarest of hybrids: a book that can sit impeccably on a coffee table or a scientist's shelf. More than 250 stunning photographs capture the beauty of amphibians as well as their bizarre adaptations and behavior. Here are lime-green tree frogs with bulging carmine eyes, sand toads with inflated vocal sacs, mismatching salamanders, and an Australian frog that gives birth to its young through its mouth. The text is just as engrossing. Essays by 37 world experts detail amphibian nervous and digestive systems, examine parenting skills,

analyze the frog leap, trace amphibians' history with humans, offer tips to terrarium keepers and photographers—and more. —S.B.K.



books

HEROES, ROGUES, AND LOVERS: TESTOSTERONE AND BEHAVIOR

**James McBride Dabbs
with Mary Godwin Dabbs
McGraw-Hill, \$24.95.**

WHEN JAMES DABBS WAS GROWING UP in South Carolina in the 1950s, it was widely understood that, as Katharine Hepburn's missionary schoolmarm instructed Humphrey Bogart's soused riverboat captain in *The African Queen*, "Nature . . . is what we were put on this earth to rise above!" These days, we're more likely to regard our animal natures with curiosity—leading to a special fascination with testosterone, everyone's favorite hallmark of our bestial past.

Dabbs, now a professor of psychology and head of the social/cognitive psychology program at Georgia State University, has traced our growing interest in testosterone and examined its potent effects on individuals and society. He maintains that the hormone gives us energy, ambition, and daring. Without it, he suggests, we'd be human shrinking violets, too shy to leave the cave and too sluggish to invent the wheel. But testosterone also spawns impulsive crimes and barroom brawls,

not to mention idiotic action flicks and leering men's magazines.

Dabbs offers great tidbits about "T," as scientists affectionately call testosterone: While the hormone appears to sharpen our focus and concentration on a single task, it detracts from our ability to attend to several things at once. Although the average guy churns out eight to 10 times as much testosterone as the average woman, female bodies appear to be much more sensitive to small amounts of the hormone. And because testosterone levels fall in men as they age, and rise in women in relation to dropping levels of the female hormone estrogen, the sexes actually become more alike as they age.

The information here ranges from the significant (men with high levels of testosterone die younger, perhaps because they do more fighting and risk-taking and less consensus-building) to the quirky (levels of the hormone are lower among vegetarians, possibly because there are natural estrogens in the plants they eat). But all of it is irresistible, especially Dabbs's original research on the varying levels of testosterone found among people in different fields or in different situations. Dabbs is campaigning to get everyone from housewives to drill sergeants to "spit for sci-

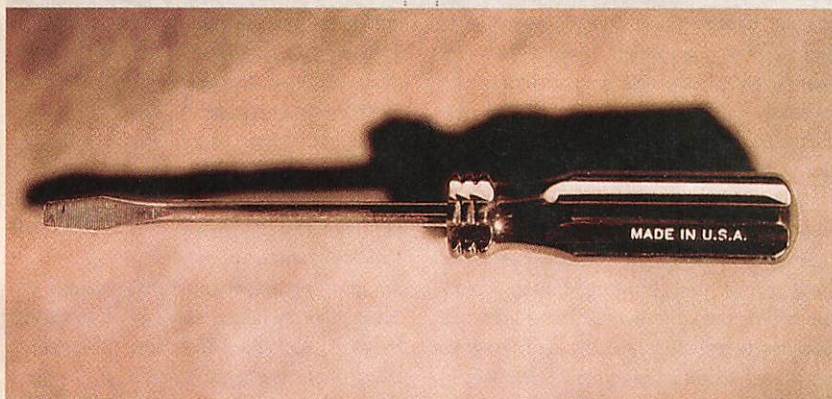


ence"—that is, submit a saliva sample for testosterone testing.

From his data, Dabbs has created a predictable portrait of the high-testosterone man: On average, he's "leaner, balder, more self-confident, more rambunctious, less likely to have friendly smiles, and more likely to favor tattoos and gold jewelry than other men." As we might expect, football players and construction workers are relatively high in testosterone, whereas intellectuals and administrators are relatively low. Firefighters'

testosterone rises on the way to a blaze and declines once they're safely away from the fire and headed back to the station.

Such details are so much fun it seems almost churlish to point out that they don't really tell us much. We need to get inside the black box of testosterone and find out exactly how it affects us physiologically before we can talk knowledgeably about the kind of person it produces. Without such critical information, Dabbs's data will remain more intriguing than illuminating. —Annie Murphy Paul



ONE GOOD TURN: A NATURAL HISTORY OF THE SCREWDRIVER AND THE SCREW

Witold Rybczynski
Scribner, \$22.

WHEN WITOLD RYBCZYNSKI WAS ASKED to pen a magazine piece about the best tool of the past millennium, he was stumped. The hammer, auger, saw, drill, and plumb line all turned out to predate the last 1,000 years. More recent innovations, such as power tools, amount to mere laborsaving, incremental improvements. Rybczynski's wife, Shirley, finally came up with a viable candidate: "You always need a screwdriver for something," she told her husband.

In this trim volume, architect and historian Rybczynski engagingly recounts his quest into the origins of the screwdriver and its necessary adjunct, the screw. Indeed, the screw steals the show. The concept of this helical wonder has been with us in some form since the early Greeks, and Rybczynski assiduously tracks its development and use in machinery, armor, and weaponry. By the time he espies perhaps the earliest depiction of a screwdriver—in a medieval rendering of a screw-cutting lathe—it's a bit of an anticlimax.

But the screw's history engrosses right down to its daunting manufacture. As Rybczynski relates, 16th-century screw-making was a cottage industry. The threads, filed by hand, were imperfect and shallow, and screws were so expensive that they were sold individually. In the 18th century, industrialization brought consumers mass-produced screws at cheaper prices, but they still had one drawback: The machinery of the day couldn't file a screw to a point. Workers had to drill a hole into material to get the blunt screw-end started. The familiar machine-made, pointed self-starting screw didn't appear until the mid-19th century.

One of Rybczynski's most absorbing tales is of how the Phillips screwdriver—the one with the cross-slotted head—enabled its corresponding counterpart to beat out the Robertson screw, making the Phillips the world's standard. The Robertson, with an incised square socket on its head, fastens faster and tighter than the Phillips. But car manufacturers preferred the Phillips precisely because of its less-snug fit: The automated screwdrivers on the factory line popped out of the screws' recesses more easily, thus preventing over-torquing.

By telling the tale of the screw, Rybczynski has done one good turn of his own.

—Margaret Foley

we also like...

EXTINCT HUMANS

Ian Tattersall and Jeffrey Schwartz
Westview Press, \$50.

DAWN OF MAN: THE STORY OF HUMAN EVOLUTION

Robin McKie
DK Publishing, \$30.

Keeping up with the dizzying pace of fossil finds and their impact on theories of human evolution can be difficult these days. These two new books promise to bring you up to speed. Anthropologists Tattersall and Schwartz take a fossil-by-fossil approach to telling the story of our purported ancestors. Science writer McKie covers much the same ground but weaves the paleontologists' tales together in a strong narrative.

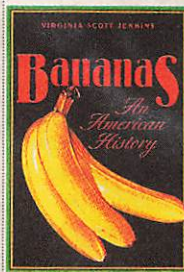
HIDDEN EVIDENCE

David Owen
Firefly Books, \$24.95.

Not for the faint of heart, this book showcases 40 high-profile crimes and the science used to crack them. With the help of lavish (and sometimes grisly) illustrations, Owen discusses everything from matching dental records and DNA to performing autopsies and gas chromatography studies. Once you're finished you'll understand the telltale marks of drowning or bombing, but you won't want to eat for a while.

BANANAS: AN AMERICAN HISTORY

Virginia Scott Jenkins
Smithsonian Institution Press, \$16.95.



Americans eat an average of 75 bananas a year, yet before 1880 the fruit was almost unknown in this country. In a vivid and often funny history, Jenkins charts how shifting diets and nutritional standards at the turn of the century as well as more

recent changes in food marketing and distribution propelled the Caribbean fruit to widespread popularity and iconic stature in American culture.

ARCHIMEDES' BATHTUB: THE ART AND LOGIC OF BREAKTHROUGH THINKING

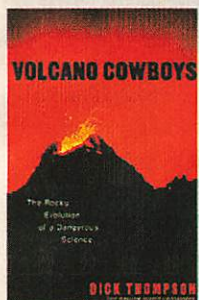
David Perkins
W. W. Norton and Company, \$24.95.

Perkins finds common cognitive principles underlie the innovative thinking of the world's foremost scientists through the ages and offers up puzzles and exercises to hone readers' creativity. By the end of this book, you may not be thinking exactly like Archimedes, but you're sure to be ready to experience your own "Eureka!" moment.

VOLCANO COWBOYS: THE ROCKY EVOLUTION OF A DANGEROUS SCIENCE

Dick Thompson

St. Martin's Press, \$26.95.



Journalist Thompson takes readers on a harrowing ride with the scientists who study the world's most dangerous natural event. Dropping into craters of active volcanoes, they measure gases and monitor seismographs in an effort to predict when eruptions will occur.

SEXING THE PARROT: CHANGING THE WORLD WITH DNA

Wilson Hall

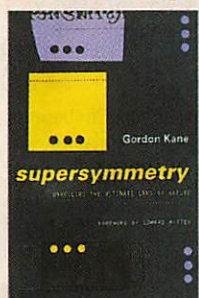
Cassell, \$27.95.

With the Human Genome Project gathering speed, don't be left behind the genetics curve. Hall, a geneticist, uses simple, lively prose to explain the intricacies of DNA developments, including gene therapy and genetically modified food. He also examines their enormous ethical implications. As a bonus, you'll learn how geneticists can now more easily determine the sex of parrots, sparing the birds from invasive (and potentially fatal) endoscopy.

SUPERSYMMETRY: UNVEILING THE ULTIMATE LAWS OF NATURE

Gordon Kane

Perseus Publishing, \$26.



Particle physicist Kane elegantly makes the case for a theory that, if confirmed, could alter our understanding of how matter works.

Supersymmetry posits that every particle has a "superpartner" that can be detected only when the two are smashed together at very high

energy levels. Quarks have "squarks," electrons have "selectrons," and so on. Kane guides us through this often bewildering subatomic world and its implications. A glossary helps readers who have trouble telling a muon from a gluon.

THE EIGHTH CONTINENT: LIFE, DEATH, AND DISCOVERY IN THE LOST WORLD OF MADAGASCAR

Peter Tyson

William Morrow, \$27.50.

Part field report, part travelogue, part ecological history, Tyson's book is an engrossing testament to one of the planet's most astonishing places. His tales from the field, by turns moving and hilarious,

are interwoven with descriptions of the island's bizarre wildlife—from screaming geckos to upside-down trees—and their uncertain future at the hands of the Malagasy, who are desperate for fuel wood and farmland. Read this book to get a sense of what future generations may be missing.

STINGING TREES AND WAIT-A-WHILES: CONFESSIONS OF A RAINFOREST BIOLOGIST

William Laurance

University of Chicago Press, \$25.

For an unusually candid look at the tribulations of fieldwork, pick up ecologist Laurance's firsthand account of his 18 months in northeastern Australia's fragmented tropical rain forest. The

ardent conservationist must contend with hostile loggers as well as suspicious farmers, unruly volunteers, and resistant government officials.

HENRY NORRIS RUSSELL: DEAN OF AMERICAN ASTRONOMERS

David H. DeVorkin

Princeton University Press, \$49.50.

Known as "the General," Henry Norris Russell transformed American astronomy from a simple observation of the stars into a quest to understand the origins of the universe. This meticulous, scholarly biography traces Russell's development into an innovative astrophysicist even as he clung fiercely to his Presbyterian faith.

—Compiled by Eric Powell

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Digital Dexterity

BY SCOTT KIM

IT'S EASY TO MAKE A CIRCLE by touching your left and right thumbs and left and right forefingers as shown here, but have you tried tying your fingers into knots? See if you can contort your digits to form the knots shown below. (Note: You need thin, flexible fingers to do figures 2 and 3; not everyone's fingers are long enough to reach.)

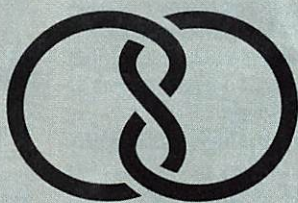
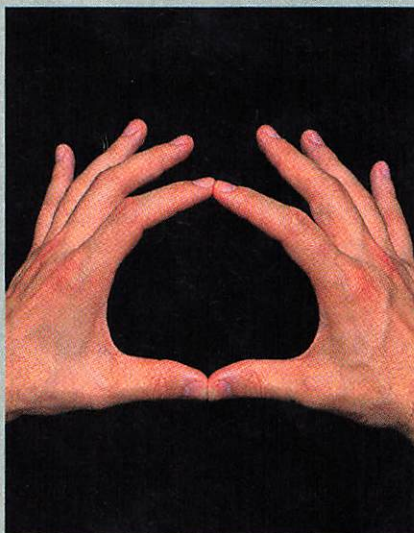
1. **{EASY}** Joining thumbs to forefingers, can you make a figure eight as shown below?



2. **{MEDIUM}** Using only your thumbs and forefingers, can you make an open figure eight, as shown below?



3. **{HARD}** Using only your thumbs and forefingers, can you make a closed overhand knot, as shown at right? It's OK to distort the knot, as long as it stays connected in one continuous loop. Find two different solutions: one that joins thumbs to forefingers, and one that joins thumb to thumb and forefinger to forefinger.



Scrambled Geometry

{MEDIUM} We've scrambled 12 words that you might remember from geometry class to form the quirky phrases below. Can you rearrange the letters of each phrase to make a familiar geometry term? Here are 12 hints to help you out (one hint per phrase, in no particular order): across the middle; it's all the same; around the edge; three-dimensional; divide and conquer; exaggerated curve; four faces; rickety rectangle; symmetrical triangle; the right stuff; the third side; triangle measurement. To get you started, the answer to the first phrase is *parallelogram*, and the hint is *rickety rectangle*.

- | | | | |
|-------------------|-------------------|-----------------|-----------------|
| 1. alarm galloper | 4. grey tin motor | 7. prime tree | 10. sees coils |
| 2. barley hop | 5. hop dearly | 8. read time | 11. to scribe |
| 3. earth rodent | 6. nuclear dipper | 9. relate quail | 12. upset honey |

Base Impulses

We might very well have our 10 fingers to thank for our use of the base 10 system. If we had 12 fingers, chances are we would count in base 12. In our base 12 world, digits 0 through 9 would stay the same, but 10 and 11 would be represented by two "new" digits, let's say T and E. And instead of the tens, hundreds, and thousands places, we would have the 12s, 144s (12×12), and 1,728s places ($12 \times 12 \times 12$). Note that from right to left, every successive place is 12 times greater than the previous place.

In general, the place values in any base n to the left of the decimal point are the ones place, the n 's place, the n squared place, the n cubed place, and so on. The place values to the right of the decimal point are the $\frac{1}{n}$ place, the $\frac{1}{n}$ squared place, and so on. To compute the total value of a number in base n , we multiply each digit by its place value and add up all the products.

1. **{EASY}** How would you write the number 1,967 in base 12?

2. **{EASY}** In base 10, the fraction $\frac{1}{9}$ is equal to the repeating decimal fraction .1111... How would you write $\frac{1}{9}$ as a fraction in base 12?

3. **{MEDIUM}** Here's a weird one. In base -10 we count using the 10 digits 0 through 9, in which we have the ones place, the negative tens place, the *positive* hundreds place (-10×-10), the *negative* thousands place ($-10 \times -10 \times -10$), and so on. How would you write 1,967 in base -10? There are actually two ways of writing every number in base -10. Can you find the other way of writing 1,967?

4. **{MEDIUM}** How would you write 1,967 in base $\frac{1}{10}$?

5. **{HARD}** How would you write 1,967 in base 10 if, instead of the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9, we used the digits -5, -4, -3, -2, -1, 0, 1, 2, 3, and 4?

FOR BOGGLERS SOLUTIONS, TURN TO PAGE 102. FOR MORE BOGGLERS PUZZLES, GO TO WWW.DISCOVER.COM.

The following books, journals, and Web sites provide additional information about topics featured in *Discover* this month.

15 R&D

"The Crack Kid Myth." The study of children exposed to cocaine in the womb was originally presented by Drs. Behnke and Eyler at the May 2000 joint meeting of the Pediatric Academic Societies and the American Academy of Pediatrics in Boston. A detailed account of Barbara Strupp's study appears in the August issue of *Behavioral Neuroscience* ("Prenatal Cocaine Exposure Impairs Selective Attention: Evidence From Serial Reversal and Extradimensional Shift Tasks," H. Garavan et al.). For more news about cocaine and pregnancy research, see www.lindsmith.org/cites_sources/brief2.html.

"Beam Me Up, Barbie." More information about these storytelling baubles appears at wwwc.media.mit.edu/StoryBeads.

"A Broccoli-Eating Croc?" "A Pug-nosed Crocodyliform From the Late Cretaceous of Madagascar," Greg Buckley et al., *Nature*, June 22, 2000, p. 941.

"Robot Watch." "A Physical Implementation of the Self-reconfiguring Crystalline Robot," Daniela Rus and Marsette Vona, 2000 IEEE International Conference on Robotics and Automation, San Francisco, April 2000; see www.ieee.org for proceedings. Also see www.cs.dartmouth.edu/~rus/self-reconfig.html for images of self-reconfiguring robots and www.ai.mit.edu/~vona/xtal for papers and more images.

"Ask the Wizard." The NASA Web site offers extensive information on space medicine: jem.tksc.nasda.go.jp/med/index_e.html. Those truly interested in the biology of spaceflight should check out *A Strategy for Research in Space Biology and Medicine in the New Century*, The Space Studies Board Committee on Space Biology and Medicine, National Academy Press, 1999.

"Sexing the Genome." "M6P/IGF2R Imprinting Evolution in Mammals," J. Keith Killian et al., *Molecular Cell*, April 2000. For the latest news about imprinted genes, see www.geneimprint.com.

THIS MODEL OF A HATCHING EGG WAS BASED ON FOSSILIZED REMAINS, BUT WE MAY NEVER TRULY KNOW WHAT THIS PROTOCERATOPS LOOKED LIKE.

"Red Waterworld." To read Carleton Moore's study of the Nakhla meteorite, see "Water Soluble Ions in the Nakhla Martian Meteorite," Douglas J. Sawyer et al., *Meteoritics & Planetary Science*, July 2000. Also see "Insights into Martian Water Reserves From Analyses of Martian Meteorite QUE94201," Laurie A. Leshin, *Geophysical Research Letters*, July 15, 2000.

"Flying Pumpkins." More information on the ultra-long-duration balloon project is available at www.wff.nasa.gov/~uldb.

"Big Burn." For up-to-date statistics on wildfires, as well as links to the regional fire centers and other fire resources, visit the National Interagency Fire Center at www.nifc.gov.

"Landmarks." For a look at the art of Lascaux, see www.sor.inria.fr/~pierre/lascaux. Also visit the Virtual Lascaux site maintained by the French Ministry of Culture. The site has lovely photographs and also describes the 20th-century discovery of the cave and the decades-long efforts to preserve it: www.culture.fr/culture/arcnat/lascaux/en.

Profiles of MacArthur Award winners can be found at www.macfound.org.

"Elixir of Spider Spit." Glenn King's spider venom study appeared in *Nature Structural Biology*, June 2000 ("Discovery and

Characterization of a Family of Insecticidal Neurotoxins With a Rare Vicinal Disulfide Bridge," Xiu-hong Wang et al.). Fred Sachs's work was published in the *Journal of General Physiology*, Vol. 115, May 2000 ("Identification of a Peptide Toxin From *Grammostola spatulata* Spider Venom That Blocks Cation-selective Stretch-activated Channels," Thomas Suchyna et al.). For a guide to spider biology, see www.xs4all.nl/~ednieuw/Spiders/InfoNed/The_spider.html.

"A Kernel of Style." Extensive information and downloadable fact sheets are on www.cdply.com.

"Master of the Micro World." One of Mark Reed's most recent papers is "Large On-Off Ratios and Negative Differential Resistance in a Molecular Electronic Device," J. Chen, M.A. Reed, A.M. Rawlett, and J.M. Tour, *Science*, November 19, 1999. Reed's Web site is www.eng.yale.edu/faculty/vita/reed.html and his lab's site is optik.eng.yale.edu/~reedgroup. For Reed's seminal paper on quantum dots, see M. A. Reed, J. N. Randall, R. J. Aggarwal, R. J. Matyi, T. M. Moore, and A. E. Wetsel, "Observation of Discrete Electronic States in a Zero-dimensional Semiconductor Nanostructure," *Physical Review Letters* 60, p. 535 (February 1988).

"Ring of Fire." IMAGE images and other information about the mission can be found at image.gsfc.nasa.gov.



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28 FUTURE TECH

The Web site of the International Biometric Industry Association has some basic information about biometrics as well as links to other biometrics sites: www.ibia.org.

For more information about Viisage Technology, visit the company's Web site: www.viisage.com.

Surf to www.iriscan.com for more information about the company and its products and for a description of the technology.

For more about I/O Software, see their Web site: www.iosoftware.com.

The Electronic Privacy Information Center's Web site offers news about electronic threats to individual liberties, details about upcoming conferences, and links: epic.org.

34 THE BIOLOGY OF... MORNING SICKNESS

"Morning Sickness: A Mechanism for Protecting Mother and Embryo," Samuel M. Flaxman and Paul W. Sherman, *The Quarterly Review of Biology*, June 2000, Vol. 75, No. 2.

"Antimicrobial Functions of Spices: Why Some Like It Hot," Jennifer Billing and Paul W. Sherman, *The Quarterly Review of Biology*, March 1998, Vol. 73, No. 1.

To find tips from the American Academy of Family Physicians on relieving morning sickness, see home.aafp.org/patientinfo/mornsick.html.

40 WORKS IN PROGRESS

For an overview of the ethnography project, visit the Web site of the Alfred P. Sloan Foundation: www.sloan.org/programs/stndrd_dualcareer.htm.

For more about the University of Michigan's Center for the Ethnography of Everyday Life, see www.ethno.isr.umich.edu.

Bowling Alone: The Collapse and Revival of American Community, Robert D. Putnam, Simon & Schuster, 2000. For Putnam, the decline in bowling clubs signifies a much larger withering of the kinds of informal gatherings that once held Americans together.

Hot Towns: The Future of the Fastest Growing Communities in America, Peter McGuire Wolf, Rutgers University Press, 1999. Wolf

describes how the influx of "lifestyle" migrants is changing these boomtowns.

46 VITAL SIGNS

For a detailed explanation of the physiological effects of decompression sickness, visit www.mtsinai.org/pulmonary/books/scuba/sectioning.htm.

50 SKY LIGHTS

For more information on the motion of Earth and the Local Group, see louis.lmsal.com/PR/answerbook/motion.html.

Find answers to your most pressing astronomy questions and browse an archive of answers to questions posed by other curious astrophiles: imagine.gsfc.nasa.gov/docs/ask_astro/ask_an_astronomer.html.

54 NEPTUNE RISING

Neptune, Gregory L. Vogt, Bridgestone Books, 2000. An excellent overview for young readers, filled with photos from Hubble and Voyager 2.

Atlas of Neptune, Garry E. Hunt, Patrick Moore, and Albert Hunt, Cambridge University Press, 1994. This volume describes Neptune and its satellites—and our efforts to understand them—in a readable fashion.

For an on-line peek at Neptune, visit NASA's gallery of planetary images: photojournal.jpl.nasa.gov.

For astronomy buffs, the Web site space.com offers a searchable archive.

Views of the Solar System, a wonderful on-line resource, includes a thorough introduction to Neptune: www.solarviews.com/eng/neptune.htm.

David Jewitt, a University of Hawaii astronomer who helped discover the Kuiper Belt, discusses his research and keeps tabs on the denizens of the outer solar system at www.ifa.hawaii.edu/faculty/jewitt/kb.html.

60 TO SAVE A WATERING HOLE

For more on Reuven Yosef's work in Eilat, read his article "An Oasis in Eilat," *Natural History*, October 1996, Vol. 105, pp. 46-47.

To assist with Yosef's field studies in Eilat as a volunteer observer, call Earthwatch Institute at 1-800-776-0188, ext. 188, or see www.earthwatch.org/expeditions/yosef.html.

To monitor migratory birds, Israeli ornithologists use satellite transmitters, radar, video, and volunteer observers. To see some of the images and data they've gathered, go to The Migrating Birds Know No Boundaries site, sponsored in part by The Society for the Protection of Nature in Israel and the Israeli Ornithological Center, at www.birds.org.il.

For more about migratory birds, see the Web site of the Smithsonian Migratory Bird Center at the National Zoo in Washington, D.C. (web2.si.edu/smbc).

66 SWEAT TECH

For detailed, illustrated descriptions of the demands and maneuvers of 120 different sports, see the just-published *Sports: The Complete Visual Reference*, edited by François Fortin (Firefly Books, \$39.95).

74 WHAT DID DINOSAURS REALLY LOOK LIKE?

We thank the American Museum of Natural History for their kind assistance in allowing us access to the museum to create the photograph that appears on pages 74-75.

The Last Dinosaur: The Life and Times of a Cultural Icon, W.J.T. Mitchell, University of Chicago Press, 1998. Why do we like dinosaurs so much? This book has the answers.

Chicago haircutter John Lazendorf owns the world's largest collection of dinosaur art. Get a peek at his collection in *Dinosaur Imagery: The Science of Lost Worlds and Jurassic Art (The Lazendorf Collection)*, Philip J. Currie et al., Academic Press Limited, 2000.

The dino-committed should enjoy the exhaustive, aptly named compendium *The Complete Dinosaur*, James O. Farlow et al., Indiana University Press, 1999.

The Web is crawling with dinosaur illustrations, and the Web site of the Museum of Paleontology of the University of California at Berkeley keeps a good list of links: www.ucmp.berkeley.edu/diapsids/dinolinks.html.

The home pages of several paleo-artists can be found at www.indyrad.iupui.edu/public/jrafert/dinoart.html.

The Web site Dinotreker (www.dinotreker.com) offers plenty of illustrations of dinosaurs,

including some by paleo-life artist Mark Hallett, as well as a useful dino timeline and links to other ancient-life sites.

For more information about the Fighting Dinosaurs exhibit at the American Museum of Natural History in New York City, see www.amnh.org.

Douglas Henderson's Earth History Illustrated Web site offers, among other things, an account of what drew Henderson to his field and a timeline with illustrations of life on Earth during different periods: gallery.in-tch.com/~earthhistory. Henderson's new book *Asteroid Impact* (Dial Books for Young Readers, 2000), which will be coming out this fall, depicts the end of the dinosaur age. Although this is a children's book, Henderson goes to great lengths to render the last days of the dinosaurs in scientifically accurate detail.

Lavishly illustrated, Peter Dodson's *The Horned Dinosaurs* (Princeton University Press, 1996) is an in-depth introduction to the suborder Ceratopsia, including its most famous member, *Triceratops*.

82 DOWNLOADING YOUR BODY

Our thanks to Charity Hospital, New Orleans, for the use of an operating room as the setting for the photograph that appears on page 82.

For more information about the ASPIRE surgical planning software, see www.med.stanford.edu/aspire.

86 BIOBOTS

At the *Robo sapiens* Web site, you can learn more about Peter Menzel and Faith D'Aluisio's upcoming book: robosapiens.mit.edu.

For more information about the robots (and their creators) featured in this book excerpt, consult the following Web sites:

For more of Mark Tilden's robots and information about how to start making robots like his, see www.beam-online.com.

RHex: See ai.eecs.umich.edu/RHex.

"Design, Modeling and Preliminary Control of a Compliant Hexapod Robot," Uluç Saranlı, Martin Buehler, and Daniel E. Koditschek, Proceedings of the 2000 International Conference on Robotics and Automation; see www.ieee.org for proceedings.

www.beyonddiscovery.org

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re sources

Ariel: www.isr.com/research/ariel.html.

For the studies that inspired both Ariel and RHex, check out "See How They Run," Carl Zimmer, *Discover*, September 1994.

Lobster robot: www.dac.neu.edu/msc/burp.html.

Robo-Geckos: For more about the actual reptiles, see www.lclark.edu/~autumn/private/u38j47a0t, which features images of

gecko foot hairs and other details. For more research on different gecko characteristics, see www.lclark.edu/~autumn/dept/index.html and polypedal.berkeley.edu. For information about the geckos' robot counterparts, see polypedal.berkeley.edu/Bioinspire/Robotics.html and www.isr.com/research/gecko.html.

"Adhesive Force of a Single Gecko Foot-hair," Kellar Autumn, Yiching A. Liang, S. Tonia Hsieh, Wolfgang Zesch, Wai Pang Chan,

BOGGLERS SOLUTIONS

DIGITAL DEXTERITY

These pictures show what you should see when you make knots with your own hands. For more mathematical hand games, see www.mathdance.com.

1.

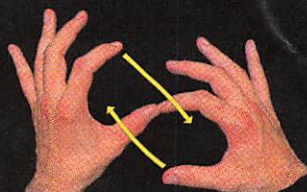


2.



3. In the first version of this knot, your fingers face away from you. The left forefinger touches the right thumb behind the right forefinger and left thumb. In the second version, the knot faces you.

VERSION 1

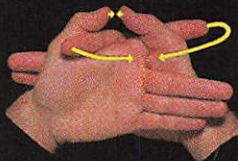


STEP 1



STEP 2

VERSION 2



STEP 1



STEP 2

SCRAMBLED GEOMETRY 1. alarm galloper = parallelogram 2. barley hop = hyperbola 3. earth rodent = tetrahedron 4. grey tin motor = trigonometry 5. hop dearly = polyhedra 6. nuclear dipper = perpendicular 7. prime tree = perimeter 8. read time = diameter 9. relate quail = equilateral 10. sees coils = isosceles 11. to scribe = bisector 12. upset honey = hypotenuse

BASE IMPULSES 1. 117E 2. .14 3. 18,047 and -2,173 (Every number in a negative base can be expressed in two ways: with or without a negative sign.) 4. 7.691 5. 2,0-3-3 (That's a four-digit number whose third and fourth digits are -3.)

Thomas W. Kenny, Ronald Fearing, and Robert J. Full, *Nature*, June 8, 2000.

For more on biologically inspired robots, see "Biological Inspiration: Lessons from Many-Legged Locomotors," Robert J. Full, International Conference on Field and Service Robots, August 29-31, 1999, Carnegie Mellon University.

"Biologists and Engineers Create a New Generation of Robots That Imitate Life," Gary Taubes, *Science*, April 7, 2000;

www.sciencemag.org.

94 REVIEWS

For an account of how scientists are investigating the apparent rise in deformed amphibians, see *A Plague of Frogs: The Horrifying True Story*, William Souder (Hyperion, March 1999).

To get a taste of the sounds and sights of the Detroit Zoo's amphibian exhibit, visit www.detroitzoo.org.

98 BOGLERS

For more puzzles and inventions by Scott Kim, see his Web site, www.scottkim.com, or his book *Inversions: A Catalog of Calligraphic Cartwheels*, Key Curriculum Press, 1996.

104 BRAINWORKS

New research suggests that the shape of the homunculus may have as much to do with genes as with sensory input:

www.eurekalert.org/releases/hms-goe033000.html.

For another example of how to map the homunculus, see www.accessexcellence.org/AE/AEC/AEF/mapping.html.

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BY ERIC HASELTINE

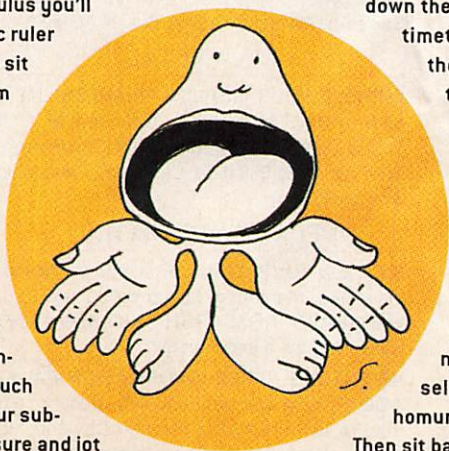
YOU HAVE A PRETTY GOOD IDEA OF what you look like from staring into the mirror each morning. But your body's appearance is radically different from the way your brain perceives it, because the sensory nerves in your skin that send messages to the brain are more densely packed in some areas than in others. For example, the touch sensors in a single fingertip are 15 times more numerous than those on the legs, so the area of the cerebrum—the somatosensory cortex—representing one finger is much larger than that representing a leg. This means that the brain's skin-sensation map, called the *homunculus*, or "little person," looks weird. Try the two experiments on this page to find out more about how your body looks to your brain.



EXPERIMENT 1 Place the tip of your tongue under your front teeth and feel the small ridges of their cutting surfaces. Now place the back of your hand against the same teeth, observing how much less sensory detail is perceptible. That's because there are more

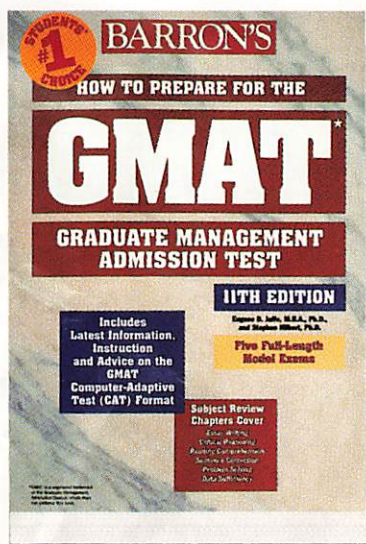
than 15 times as many touch receptors per square inch on your tongue than there are on the back of your hand. Your homunculus thus shows considerably more space devoted to the tip of your tongue than it does to the skin on the back of your hand.

EXPERIMENT 2 To draw your own homunculus you'll need a notepad, two toothpicks and a metric ruler to gather data. Persuade a trusting friend to sit with his eyes closed while you gently stick him with the pointy ends of the two toothpicks at these 10 body locations: middle of the forehead; right temple; right cheek; meaty part of the upper lip; middle of the right bicep; tip of the right index finger; Adam's apple; stomach just above the belly button; upper thigh; and tip of the right big toe. For each point, start by positioning the toothpicks close together. Then gradually move the toothpicks farther apart, making sure they both touch the skin at the same time. Keep asking if your subject feels one point or two as you poke. Measure and jot



down the distance between the toothpicks—in centimeters—the first time your friend says "two," then move on to the next location and repeat the entire process. When I tried this, I first made a "normal" sketch of myself using the measurements from 10 different patches of my skin, which I then used to produce the homuncular self-portrait at left. For example, I took the two-point distance on my stomach, 4 centimeters, and multiplied its reciprocal (0.25) by the size of the normal torso in my drawing to come up with this minuscule torso. Make a rough sketch of yourself, then distort it with the scale factors for a homunculus collected from your own experiment. Then sit back and look your own brain in the eye.

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